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ALGORITHM FOR SURFACE OF TRANSLATION ATTACHED RADIATORS (A-STAR): User's Manual

McDonnell Douglas Corporation

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A hierarchy of computer programs implementing the method of moments for bodies of translation (MM/BOT) is described. The algorithm treats the far-field radiation from off-surface and aperture antennas on finite-length open or closed bodies of arbitrary cross section. The near fields and antenna coupling on such bodies are computed. The theoretical development underlying the algorithm is described in Volume I of this report.

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The structure of the computer algorithm is such that no a priori knowledge of the method of moments technique or detailed FORTRAN experience are presupposed for the user. A set of carefully drawn example problems illustrates all the options of the algorithm. For more detailed understanding of the workings of the codes, special cross referencing to the equations in Volume I is provided. For additional clarity, comment statements are liberally interspersed in the code listings, summarized in Volume III.

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1. INTRODUCTION

This manual is divided into two parts. Section 2 constitutes the user section, describing the overall flow of the codes, input data requirements, and parameter relations. At the end of the section, a series of sample problems is given to illustrate the use of the codes. The sample problems exercise all parts of the A-STAR codes and serves as a check case for the installation of the codes on a given machine. The problems are arranged in increasing computational complexity. Section 3 provides a detailed description of all codes and subroutines. The user need not refer to Section 3 or to the analysis in Volume I of this report to successfully install and execute the programs on a particular computer system.

1.1 Formulation and Method of Solution

A detailed description of the theoretical formulation forming the basis of the A-STAR programs is given in Volume I. The analysis is based on the solution of the generalized electric-field integral equation (EFIE) for all the BOT configurations treated with the method of moments (MM) technique. The unknown currents on the surface of the body and the antennas are expanded in a series of expansion functions appropriate to each of the major parts of the BOT configuration: the BOT surface, the caps, the wire radiators, the junction, and the edge transition regions on the body. The formulation allows the effect of some or all of these components to be treated. The resulting analysis and implementing computer programs provide a unified treatment of a broad class of radiation/scattering problems associated with radiators on asymmetric surfaces.

1.2 Program Features

A partial synopsis of salient features and options of the A-STAR codes is given below:

Flexible body geometry - The algorithm can treat a finite-length BOT of any asymmetric cross section. The BOT can be open or closed (i.e., capped). The caps are assumed to be planar and perpendicular to the axis of translation of

the BOT. Degenerate forms of a BOT configuration can also be analyzed with this algorithm such as flat plates, parabolic and square cylinders, and disks (circular or noncircular).

Arbitrary aperture antenna placement and excitation - The algorithm treats single or multiple rectangular aperture (slot) antennas embedded in the BOT surface. Location of the antennas can be anywhere on the BOT except the caps. Spacing between adjacent apertures can be electrically small. All apertures can be asymmetric.

Arbitrary off-surface (wire) antenna placement and excitation - A wide variety of wire antenna configurations such as monopoles and loops, both active and passive, can be treated with these codes. The antennas can be anywhere on or near the BOT surface. (Location of an antenna on the caps is excluded.) The user can specify the use of a special junction representation for the antenna attachment points on the BOT, which is of special importance in the treatment of parasitic elements.

Surface currents - The algorithm outputs the surface currents on the BOT surface in spatial and modal form. Both the magnitude and the phase of the t- and z-directed components are given.

Choice of polarization and radiation planes - The radiated fields and the power gain, normalized to an isotropic radiator, are given in the user-specified plan for θ and ϕ polarization.

Arbitrary choice of sampling points for near fields - The electric and magnetic fields (six components in all) resulting from currents induced by antennas on a general BOT or induced by incident fields are computed at user-specified points in the vicinity of the BOT surface.

User-oriented program features - The programs are liberally interspersed with comment statements referring to Volumes I and II. The codes are modular, and error checking is provided for the user at critical steps in the computation sequence. The input data requirements are minimized. All inputs are printed out for user verification.

Sample problems - The unique features of the algorithm are demonstrated with sample problems in Section 2.6. The problems have been tested and compared with corresponding results using other methods and available experimental data.

As in all mathematical and numerical modeling, caution must be exercised in applying the analysis to certain cases where there are abrupt discontinuities in the BOT surface and at resonance conditions. To achieve sufficient accuracy, a large number of modes and surface (triangle) expansion functions may be necessary for these problems.

2. USER SECTION

The A-STAR computer codes are written in FORTRAN IV, consisting of six impedance generation programs (i.e., BOTZSS, BOTZSW, BOTZWW, BOTZSC, BOTZCC, and BOTZCW), two matrix inversion programs (i.e., BOTINV and BOTINVA), four EM signature prediction codes (i.e., BOTAC, BOTRA, BOTSCM, and BOTSCB), and one utility program (BOTSEG) as shown in Figure 1. All of the programs have user-oriented inputs, which can be generated easily for a given problem. In addition, binary files are generated for the impedance matrices and the inverted matrices by several of the programs. Examples demonstrating the input data and output from each of the programs are discussed in the sample problems (Section 2.6).

2.1 Implementation of Computer Codes

All of the A-STAR computer codes are written in USA Standard FORTRAN IV, with the exception of end-of-file (EOF) checks in programs BOTINV, BOTINVA, BOTAC, BOTRA, BOTSCM, and BOTSCB. The EOF checks given in the code listings in Volume III are specific to the compiler used in the program development (i.e., CDC CYBER 175 system). The functioning of the EOF checks in the present listings is as follows:

IF EOF(u) a, b

u - unit number to check.

a - statement label to branch to if an EOF is encountered.

b - statement label to branch to if an EOF is not encountered.

The device unit numbering convention is as follows:

unit number 5 - card reader

unit number 6 - line printer

unit number 7 - binary output file. Each of the six impedance-generating codes creates a new binary output file on unit number 7 for storing impedance matrices. The two inversion codes create a new binary output file on unit number 7 for storing the new inverted system matrix (see Figure 1).

unit number 1 - binary input file. Each of the four EM signature codes reads the inverted system matrix from unit number 1. The BOTINVA

inversion code reads the old inverted system matrix from unit number 1. The BOTINV inversion code reads the BOT-BOT impedance matrix from unit number 1 (see Figure 1).

unit number 2 - binary input file, which is read by the BOTINVA code. It should contain the BOT-wire impedance matrix when wires are being added to the old system matrix, and the BOT-cap impedance matrix when caps are being added.

unit number 3 - binary input file, which is read by the BOTINVA code. It should contain the cap-wire impedance matrix if caps and wires are contained in the new system matrix.

unit number 4 - binary input file, which is read by the BOTINVA code. It should contain the wire-wire impedance matrix when wires are being added to the old system matrix, and the cap-cap impedance matrix when caps are being added.

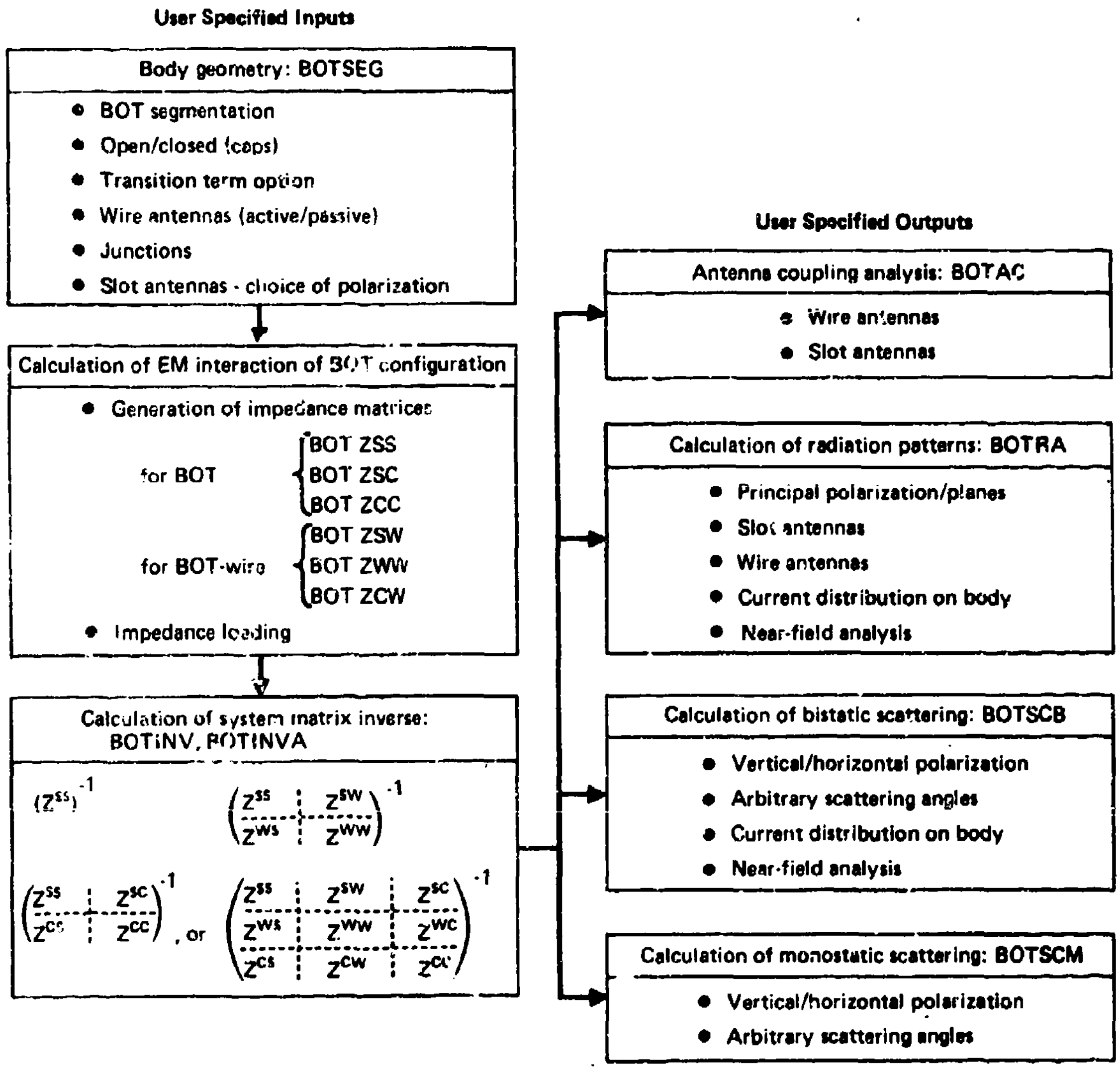


Figure 1. Major program blocks of A-STAR.

2.2 BOTSEG Description

BOTSEG is a utility program, which can be used to segment the BOT generating curve using a limited set of data points (see coordinate geometry in Figure 2). The required input data and formats are described below.

```
    READ(5,1)NPTS,NP
1   FORMAT(2I3)
```

NPTS - Number of input data points used to describe the BOT generating curve.

NP - Number of equally spaced BOT generating-curve data points to be calculated. (The calculated data are used as input to the remaining BOT programs.)

```
    DO 100 I = 1, NPTS
100 READ(5,2)XTAB(I),YTAB(I),XC(I),YC(I)
2   FORMAT(4E10.4)
```

XTAB(I) - x coordinate of the I-th point on the input curve (meters).

YTAB(I) - y coordinate of the I-th point on the input curve (meters).

XC(I),YC(I) - (meters) indicate whether the points [XTAB(I), YTAB(I)] and [XTAB(I+1),YTAB(I+1)] are connected by a straight-line segment or an arc with changing radius. If XC(I) = YC(I) = 0, the segment is straight. Otherwise, [XC(I),YC(I)] is assumed to be the center of an arc with the above end-points, where the radius changes linearly with angle from [XTAB(I),YTAB(I)] to [XTAB(I+1),YTAB(I+1)], subtending the angle of the triangle formed by the three points. If the three points are collinear, the direction of the arc is clockwise.

Example: Consider a cylinder with a cross-section given in Figure 2. The generating curve for this body can be represented with three points (NPTS = 3) as follows:

0	0	0	0
3	1	3	0
4	0	0	0

BOTSEG is currently dimensioned to handle 100 points on the input curve and 83 points on the output curve. The NP data points used to represent the BOT generating curve determine the location and number of triangle functions and their derivatives (denoted by arrays T and TP in the codes) used to discretize the unknown currents on the BOT surface. As an example, Figure 3

shows a portion of a BOT generating curve defined by points t_1, t_2, t_3 . . . t_i with the triangle functions centered at t_3, t_5, etc. The triangle functions span five data points, with adjacent functions overlapping.

2. Input Data Description and Formats

A detailed description of the input data required by all A-STAR codes (except the inversion codes, as described in Section 2.3.8) is given below. READ statements and formats are listed in the order in which they appear within the program, followed by a description of the required data.

```
    READ(5,1)BK
1   FORMAT(E15.7)
```

BK - Wave number for the problem (meters^{-1}).

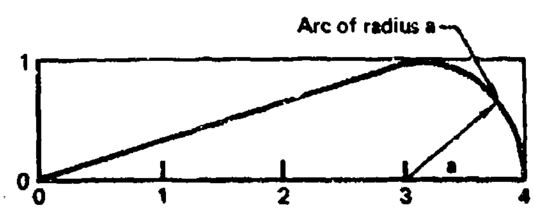


Figure 2. Representation of a BOT with a cross section formed by a wedge and arc segment.

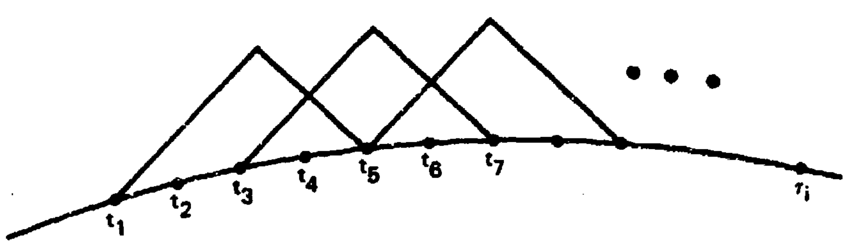


Figure 3. Triangle functions on BOT surface.

2.3.1 BOT Data Set

This data set is required by all programs.

```
    READ(5,2) NMODE,NSP,NBAND
2   FORMAT(3I3)
```

NMODE - Number of nonnegative modes to be considered (i.e., there will be 2*NMODE - 1 total modes).

NSP - Number of diagonal bands to be used in each $Z^{tt}_{m,n}$, $Z^{zt}_{m,n}$, $Z^{tz}_{m,n}$, and $Z^{zz}_{m,n}$ submatrix. NSP=1 indicates that only the diagonal terms are nonzero in each submatrix; NSP=2 indicates that only diagnonal and off-diagonal terms are nonzero, etc. If NSP > (NP-3)/2, each submatrix is full, where NP is described below.

NBAND - Number of submatrix diagonal bands to be calculated by BOTZSS. NBAND=1 indicates that only the diagonal $Z_{m,n}$ submatrices are to be calculated. NBAND=2 indicates that diagonal and off-diagonal $Z_{m,n}$ submatrices are to be calculated, etc. If NBAND > 2*NMODE-1, the entire Z_{BOT} matrix is calculated.

```
    READ(5,3)NP
3   FORMAT(I3)
```

NP - Number of points used to describe the BOT generating curve. (NP must be odd.) If the BOT generating curve is closed (i.e., the first and last points coincide), the programs will increase NP by two and add two points to the generating curve (i.e., the YB and XB arrays described below). This new NP should be used in all definitions involving NP (e.g., dimensions).

```
    READ(5,4)(YB(I),I=1,NP)
4   FORMAT(10F8.4)
```

YB - Array of y coordinates for the generating curve (meters).

```
    READ(5,5)(XB(I),I=1,NP)
5   FORMAT(10F8.4)
```

XB - Array of x coordinates for the generating curve (meters).

```
      READ(5,6)BL
6     FORMAT(F8.4)
```

BL - Half length of the BOT (meters).

2.3.2 Cap Data Set

This data set is required by all programs and is used for putting end-caps on the open BOT (see Figure 4).

```
      READ(5,7)NC,NPR,NE
7     FORMAT(3I3)
```

NC - Number of flat end-caps on the BOT.

NPR - Number of radial points used to describe each cap. (NPR must be odd.)

NE - Indicates whether or not the BOT/cap transition term is to be included. NE=0 indicates no transition terms, and NE ≠ 0 indicates that the BOT/cap transition term should be used.

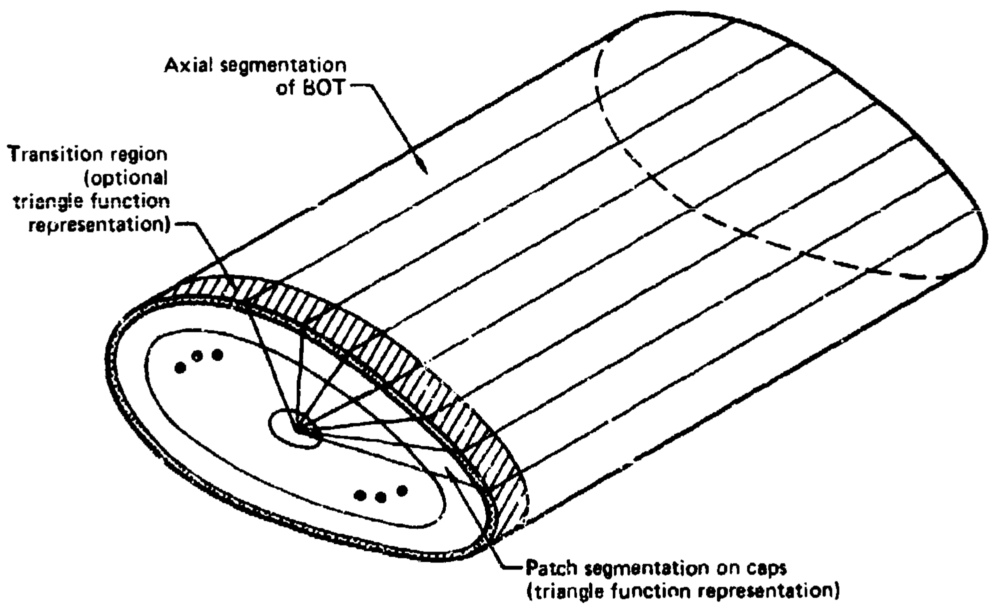


Figure 4. Representation of a capped BOT.

If NE ≠ 0, the programs set NE=NC. This new NE should be used in all definitions involving NE (e.g., dimensions).

If NC=0, the rest of this data set is ignored.

```
    READ(5,8)XC,YC
8   FORMAT(2F8.4)
```

XC - x coordinate of the cap center (meters).

YC - y coordinate of the cap center (meters).

```
    READ(5,9)(ZC(I),I=1,NC)
9   FORMAT(10F8.4)
```

ZC - Array of z coordinates for the caps (meters).

```
    READ(5,10)(RHOC(I),I=1,NPR)
10  FORMAT(10F8.4)
```

RHOC - Array of normalized radial coordinates used to describe the caps.
(0< RHOC(I)<RHOC(I+1)≤1.)

If NE ≠0, the following is required.

```
    READ(5,11)(ZE(I),I=1,NC)
11  FORMAT(10F8.4)
```

ZE - Array of z coordinates that specifies the starting z location for the BOT/cap transition term (meters). (-BL<ZE(I)<BL.)

2.3.3 Wire Data Set

This data set is required by all programs.

```
    READ(5,12)NW,NPW,NJ
12  FORMAT(3I3)
```

NW - Number of wire antennas on the BOT. Each antenna must be represented by an odd number of points.

NPW - Total number of data points representing all of the wire antennas on the BOT.

NJ - Number of BOT/wire junction points to be included.

If NW=0, the rest of this data set is ignored.

```
   READ(5,13)(XW(I),I=1,NPW)
13 FORMAT(10F8.4)
```

XW - Array of x coordinates for the wires (meters).

```
   READ(5,14)(YW(I),I=1,NPW)
14 FORMAT(10F8.4)
```

YW - Array of y coordinates for the wires (meters).

```
   READ(5,15)(ZW(I),I=1,NPW)
15 FORMAT(10F8.4)
```

ZW - Array of z coordinates for the wires (meters).

```
   READ(5,16)(INDW(I),I=1,NW)
16 FORMAT(10I8)
```

INDW - Array containing the starting index for each antenna in the XW, YW, and ZW arrays. INDW(I) is the starting index of the I-th antenna.

```
   READ(5,17)(RADW(I),I=1,NW)
17 FORMAT(10F8.4)
```

RADW - Array containing the radii of the antennas. RADW(I) is the radius of the I-th antenna (meters).

If NJ=0, the rest of this data set is ignored.

```
   READ(5,18)(INDJW(I),I=1,NJ)
18 FORMAT(10I8)
```

INDJW - Array containing the wire index for each BOT/wire junction. Each index must correspond to a wire point which either starts or terminates an antenna at the BOT surface.

```
      READ(5,19)(RADD(I),I=1,NJ)
19    FORMAT(10F8.4)
```

RADD - Array containing the radius for each junction disk (meters).

```
      READ(5,20)(UXJ(I),I=1,NJ)
20    FORMAT(10F8.4)

      READ(5,21)(UYJ(I),I=1,NJ)
21    FORMAT(10F8.4)

      READ(5,22)(UZJ(I),I=1,NJ)
22    FORMAT(10F8.4)
```

UXJ,UYJ,UZJ - Arrays containing the x, y, and z components, respectively, of the normal vector to each junction disk. The normal vector need not be normalized to unity.

2.3.4 Aperture Antenna Data Set

This data set is read only by the BOTRA and BOTAC programs and should be deleted when running the BOTSCB and BOTSCM programs.

```
      READ(5,23)NSA
23    FORMAT(I3)
```

NSA - Number of slot antennas on the BOT.

```
      READ(5,24)(IS(K),K=1,NSA)
24    FORMAT(10I8)
```

IS(K) - Triangle function at which slot antenna K is located (centered).

```
      READ(5,25)(ZO(K),K=1,NSA)
25    FORMAT(10F8.4)
```

ZO(K) - Starting Z coordinate for antenna K (meters).

```
      READ(5,26)(Z1(K),K=1,NSA)
```

```
26  FORMAT(10F8.4)
       Z1(K) - Ending Z coordinate for antenna K (meters).
          (Z0(K) < Z1(K) for all K.)

    READ(5,27)(E0(K),K=1,NSA)
27  FORMAT(10F8.4)
       E0(K) - Constant excitation across slot antenna K (E0(K) is complex).

    READ(5,28)(TEXC(K),K=1,NSA)
28  FORMAT(10F8.4)
       TEXC(K)  - Indicates t excitation on slot antenna K when TEXC(K)=1.0.
             Set TEXC(K)=0.0 if antenna K is not excited in the t
             direction.

    READ(5,29)(ZEXC(K),K=1,NSA)
29  FORMAT(10F8.4)
       ZEXC(K)  - Indicates z excitation on slot antenna K when ZEXC(K)=1.0.
             Set ZEXC(K)=0.0 if antenna K is not excited in the z
             direction.
```

2.3.5. Wire/Junction Voltage Data Set

This data set is read only by the BOTRA program and should be deleted when running the BOTSCB and BOTSCM programs. This data set is ignored if NW=0.

```
       READ(5,30)NWJV
30  FORMAT(I3)
       NWJV  - Number of wire and/or junction voltage points.
               If NWJV = 0, the rest of this data set is ignored.

    READ(5,31)(IW(I),I=1,NWJV)
31  FORMAT(10I8)
       IW    - Array containing the NWJV voltage point indices in the wire
               voltage array to be fed. The K-th wire triangle is fed if
               IW(I)=K. The K-th junction is fed if IW(I)=(NPW-3*NW)/2 + K.
```

```
      READ(5,32)(EW(I),I=1,NWJV)
   32 FORMAT(10F8.4)
```

EW - Array containing the NWJV voltages (complex).

2.3.6 Radiation and Scattering Analysis Data Set

This data set is read by the BOTRA, BOTSCM, and BOTSCB programs.

```
      READ(5,33)NANG,NT,PHII,THI
   33 FORMAT(2I3,2F8.4)
```

NANG - Number of fixed radiation or scattering angles, as defined by IPLANE below. NANG radiation or scattering patterns will be calculated.

NT - Number of varied radiation or scattering angles, as defined by IPLANE below.

PHII - ϕ angle of incident wave (degrees). Used only in BOTSCB program.

THI - θ angle of incident wave (degrees). Used only in BOTSCB program.

```
      READ(5,34)(ANG(I),I=1,NANG)
   34 FORMAT(10F8.4)
```

ANG - Array of fixed radiation or scattering angles, as defined by IPLANE below.

```
      READ(5,35)(IPLANE(I),I=1,NANG)
   35 FORMAT(10I8)
```

IPLANE - Array indicating whether the corresponding element of array ANG is a ϕ or θ angle. IPLANE(I)=1 indicates that ANG(I) is a fixed ϕ angle. In this case, ϕ is fixed at ANG(I) and θ varies between ANG1(I) and ANG2(I) at NT equally spaced angles. IPLANE(I)=2 indicates that ANG(I) is a fixed θ angle. In this case, θ is fixed at ANG(I) and ϕ varies between ANG1(I) and ANG2(I).

```
      READ(5,36)(ANG1(I),I=1,NANG)
```

```
36  FORMAT(10F8.4)
```

ANG1 - Array of starting angles (degrees).

```
    READ(5,37)(ANG2(I),I=1,NANG)
37  FORMAT(10F8.4)
```

ANG2 - Array of ending angles (degrees).

2.3.7 Near-Field Analysis Data Set

This data set is read by the BOTRA and BOTSCB programs.

```
    READ(5,38)NTEST
38  FORMAT(I3)
```

NTEST - Number of test points at which near-field radiation or scattering is to be calculated. NTEST may be set to zero.

Repeat the following NTEST times:

```
    READ(5,39)ZTEST,YTEST,XTEST
39  FORMAT(3F8.4)
```

ZTEST - z coordinate of the test point (meters).

YTEST - y coordinate of the test point (meters).

XTEST - x coordinate of the test point (meters).

All of the above user-specified input data are checked for errors by the A-STAR codes and printed on the line-printer as a given problem is executed. In addition, the BOT generating curve is plotted on the line-printer as a visual check of the BOT input geometry (the x and y axes use the same scale for this plot). The codes BOTAC and BOTRA generate plots of the three principal views of the input geometry (these plots are not to scale). These plots can be used to check for errors, e.g., in the wire inputs and near-field points. Definitions of the symbols used in these plots are given below:

B - BOT generating curve data point

C - Cap center data point

E - Edge termination data point

J - Junction data point

N - Near-field data point

S - Slot antenna termination point

W - Wire data point

\+ - Two or more of the above symbols occupy the same line-printer position.

2.3.8 BOT Inversion Data Sets

The BOT inversion code (BOTINV) is used when the system matrix to be inverted contains the open BOT only. The following input data are required:

```
    READ(5,1)NMODE,NBAND
1   FORMAT(2I3)
```

NMODE - Number of nonnegative modes to be used for the inversion (i.e., there will be 2*NMODE-1 total modes).

NBAND - Number of submatrix diagonal bands to be used during the inversion of Z_{BOT}. NBAND=1 indicates that only the diagonal $Z_{m,n}$ submatrices are to be used during inversion. NBAND=2 indicates that diagonal and off-diagonal $Z_{m,n}$ submatrices are to be used, etc. If NBAND > 2*NMODE-1, the entire Z_{BOT} matrix is inverted.

```
    READ(5,2)(LOAD(I),I=1,NM)
2   FORMAT(10F8.4)

    READ(5,3)(LOAD(I),I=NM+1,2*NM)
3   FORMAT(10F8.4)
```

LOAD - Array containing the BOT surface impedance loading in the t and z directions, at each triangle peak on the BOT. LOAD(1) through LOAD(NM) contain the t-directed loadings, and LOAD(NM+1) through LOAD(2*NM) contain the z-directed loadings, where NM=(NP-3)/2 is the number of triangle functions on the BOT. LOAD is a complex array.

When the system matrix to be inverted contains the open BOT with wires and/or caps included, the BOTINVA code is used. The BOTINVA code can be used to perform the following types of system matrix inversion:

1) Caps can be added to a previously inverted system which does not contain caps.

2) Wires can be added to a previously inverted system which does not contain wires.

The following data are required by BOTINVA:

```
    READ(5,1)NC,NPR,NE,NW,NPW,NJ
1   FORMAT(6I3)
```

Either NC or NW must be zero.

NC - Number of end-caps to be added to the system.

NPR - Number of radial points used to describe each cap. (NPR must be odd).

NE - Indicates whether or not the BOT/cap transition term is to be included. NE=0 indicates no transition term, and NE ≠ 0 indicates that the BOT/cap transition term should be used.

NW - Number of wire antennas to be added to the system.

NPW - Total number of data points representing all of the wire antennas.

NJ - Number of BOT/wire junction points.

If NC ≠ 0, the following is required:

```
    READ(5,2)(LOAD(I),I=1,NM)
2   FORMAT(10F8.4)

    READ(5,3)(LOAD(I),I=NM+1,2*NM)
3   FORMAT(10F8.4)
```

LOAD - Array containing the BOT surface impedance loading in the t and z directions at each triangle peak on the BOT. LOAD(1) through LOAD(NM) contain the t-directed loadings, and LOAD(NM+1) through LOAD(2*NM) contain the z-directed loadings, where NM= (NP-3)/2 is the number of triangle functions on the BOT. LOAD is a complex array.

2.4 Parameter Selection

The choice of most of the parameters in the foregoing sections is specified by the user depending upon the explicit requirements of the problem. For example, NSA is set by the number of slot antennas on the BOT. Similarly, BK is determined by the frequency at which the MM/BOT analysis is carried out. On the other hand, the choice of some parameters is based upon the requirements of the MM/BOT theory, as explained below.

The parameter NMODE is set by the length of the BOT. In general, the minimum requirement is that NMODE $\gtrsim 2L/\lambda$, where L is the (axial) half-length of the BOT. This requirement is comparable to the MM/BOR analysis requirement that the maximum circumferential modes used be $n \sim \pi D/\lambda$, where D is the largest diameter of the BOR. As a general observation, the accuracy of the analysis increases and the spatial resolution of the surface currents on the BOT is improved as NMODE is increased. This trend is particularly true for the edge currents. However, practical computer main-memory limitations usually set the upper limit on NMODE.

The parameters NP, NPR, and NPW determine the spacial resolution with which the BOT generating curve, caps, and wires are described. In general, the maximum separation between data points should not exceed 0.075λ, which is equivalent to 0.15λ between triangle peaks. As a general principle, the accuracy of the analysis is improved as the separation between data points is decreased.

The parameter ZE(I) indicates the z coordinate at which the BOT/cap transition triangle function starts on the BOT. In general, ZE(I) should be located on the order of 0.15λ from the end-cap (i.e., ZC(I)).

The parameter RADD(I) specifies the BOT/junction disk radius on the BOT. In general, RADD(I) should be on the order of 0.15λ.

2.5 Program Dimensions

The A-STAR programs (Volume III) are currently configured to handle problems with the following set of parameters. (Some of the arrays are overdimensioned in the listings.)

NMODE ≤ 4

NBAND ≤ 2*NMODE-1

NP ≤ 19 (17 for a closed generating curve)

NANG ≤ 6

NT ≤ 91

NSA ≤ 20

NC ≤ 2

NPR ≤ 5

NW ≤ 2

NPW ≤ 18

NJ ≤ 2

For a different set of input parameters, the minimum dimensions required for each program are listed below. Table 1 contains definitions of the parameters used as the subscripts in the arrays listed in the dimension statements.

Table 1. DEFINITION OF DIMENSION STATEMENT INDICES

Parameter	Defintion
KMODE	2*NMODE-1; total number of modes for the BOT current expansion
LC	NC*NM*LR; total number of triangle functions on all end-caps for one component of current
LE	NE*NM; total number of BOT/cap transition triangle functions
LR	(NPR-3)/2; number of radially directed triangle functions on each cap
LS	NP-3
LW	(NPW-3*NW)/2; number of triangle functions on the wires
NANG	Scattering and radiation analysis data set input
NC	Cap data set input
NE	Cap data set input
NJ	Wire data set input
NM	(NP-3)/2; number of triangle functions on the BOT
NMODE	BOT data set input
NP	Number of points on the BOT generating curve (input). If the curve is closed, use (NP+2) in place of NP in all definitions
NPLOT	2*NP+2*NC+NPW+2*NSA+NTEST
NPR	Cap data set input
NPW	Wire data set input
NSA	Aperture antenna data set input
NT	Scattering and radiation analysis data set input
NTEST	Near-field analysis data set input
NW	Wire data set input
NWJV	Wire/junction voltage data set input

COMMON Statement Minimum Dimensions Contained in BOT Programs

```
COMMON/BOT2/NP,BL,YB(NP),XB(NP),YB1(NP-1),XB1(NP-1)
COMMON/BOT3/DH(NP-1),SV(NP-1),CV(NP-1)
COMMON/BOT5/T(4*NM),TP(4*NM),TZ(4*NM)
COMMON/WIRE1/NPW,XW(NPW),YW(NPW),ZW(NPW),XW1(NPW-1),YW1(NPW-1),ZW1(NPW-1)
COMMON/WIRE2/DHW(NPW-1),DXW(NPW-1),DYW(NPW-1),DZW(NPW-1)
COMMON/WIRE3/NW,INDW(NW+1),RADW(NW)
COMMON/WIRE4/LW,TW(4*LW),TPW(4*LW),INDTW(LW)
COMMON/JUNC1/NJ,INDJW(NJ),RADJ(NJ),RADD(NJ)
COMMON/JUNC2/TJ(2*NJ),TPJ(2*NJ),INDTJ(NJ)
COMMON/JUNC3/XJ(NJ),YJ(NJ),ZJ(NJ)
COMMON/JUNC4/UXJ(NJ),UYJ(NJ),UZJ(NJ)
COMMON/JUNC5/UXJ1(NJ),UYJ1(NJ),UZJ1(NJ)
COMMON/JUNC6/UXJ2(NJ),UYJ2(NJ),UZJ2(NJ)
COMMON/SLOT1/NSA,IS(NSA),ZO(NSA),Z1(NSA)
COMMON/SLOT2/EO(NSA),TEXC(NSA),ZEXC(NSA)
COMMON/CAP1/NC,XC,YC,ZC(NC)
COMMON/CAP2/NPR,RHOC(NPR),RHOC1(NPR-1),DRHOC(NPR-1)
COMMON/CAP3/TCR(4*LR),TCT(4*LR),TPCR(4*LR),TPCT(4*LR)
COMMON/CAP4/RC(NP),RC1(NP-1),AC(NP-1),CPC(NP-1),SPC(NP-1)
COMMON/EDG1/NE,ZE(NE),ZBE(2*NE)
COMMON/EDG2/TCE(2*NE),TPCE(2*NE),TBE(2*NE),TPBE(2*NE)
COMMON/PLOT1/NPLOT,XPLOT(NPLOT),YPLOT(NPLOT),ZPLOT(NPLOT),ISYM(NPLOT)
```

BOTZSS Minimum Dimensions

```
COMPLEX Z(LS*LS),G((NP-1)*NP/2),GB((NP-1)*NP/2)
DIMENSION TWGHT(NM),ZWGHT(NM)
```

BOTZSW Minimum Dimensions

```
COMPLEX Z(LS*(LW+NJ)),G1((NP-1)*(NPW-1)),G2((NP-1)*(NPW-1))
```

BOTZWW Minimum Dimension

```
COMPLEX Z((LW+NJ)**2)
COMMON/WIRE1/NPW,X(NPW,3)
COMMON/WIRE2/WL(NPW-1)
```

```
COMMON/WIRE3/NW,INDW(NW+1),RADW(NW)
COMMON/WIRE4/TWIRE(LW,4),TPW(LW,4),UW(NPW-1,3).
COMMON/JUNC1/NJ,RADJ(NJ),RADD(NJ)
COMMON/JUNC2/TJUNC(NJ,2),TPJ(NJ,2)
COMMON/JUNC3/XJ(NJ,3,3),WLJ(NJ,2)
COMMON/JUNC4/UJ(NJ,2,3)
COMMON/JUNC5/URT(NJ,3)
COMMON/JUNC6/URZ(NJ,3)
DIMENSION INDJW(NJ),INDTJ(NJ),UXJ(NJ),UYJ(NJ),UZJ(NJ)
```

BOTZSC Minimum Dimensions

```
COMPLEX Z(LS*(2*LC+LE)),G2((NP-1)*NC*(NP-1)*(NPR-1))
COMPLEX G1E((NP-1)*NE*(NP-1)*2),G2E((NP-1*NE*(NP-1)*2)
```

BOTZCC Minimum Dimensions

```
COMPLEX Z(4*LC*LC),GS((NP-1)*(NPR-1))
DIMENSION TWGHT(NM*LR),RWGHT(NM*LR),EWGHT(NM*NE/NC)
```

BOTZCW Minimum Dimensions

```
COMPLEX Z((2*LC+LE)*(LW+NJ))
```

BOTINV Minimum Dimensions

```
COMPLEX Z(K1),ZI(K2), LOAD(K3)
DIMENSION WGHT(K3)
DIMENSION NZ(K4)
COMMON NM,JK(4),LR(K5)
```

where K1 through K5 depend on NBAND and are defined below.

NBAND	1	<2*NMODE-1	> 2*NMODE-1
K1	0	LS^2* {(2*NMODE-1) *(2*NBAND-1)-(NBAND-1)*NBAND}	{LS*(2*NMODE-1)}^{2}
K2	LS^2	LS^2*(2*NMODE-1)	LS^2
K3	LS	LS	LS
K4	0	2*NMODE-1	0
K5	LS	LS	LS*(2*NMODE-1)

BOTINVA Minimum Dimensions

The program dimensions depend on the type of matrix inversion being performed. The four possible types along with the corresponding dimensions follow:

1) Addition of wires to an open BOT

```
COMPLEX PI((LS*KMODE)^2),Q(LS*KMODE*(LW+NJ)),R(LS*KMODE*(LW+NJ)),S((LW+NJ)^2),
   YI(max(LS*LS,(LW+NJ)^2))
COMPLEX W1(max(LS*KMODE,LW+NJ)),W2(LW+NJ)
COMPLEX LOAD(1)
DIMENSION WGHT(1)
```

2) Addition of caps to an open BOT

```
COMPLEX PI((LS*KMODE)^2),Q(LS*KMODE*(2*LC+LE)),R(LS*KMODE*(2*LC+LE)),
   S((2*LC+LE)^2), YI(max(LS*LS,(2*LC+LE)^2)
COMPLEX W1(max(LS*KMODE,2*LC+LE)),W2(2*LC+LE)
COMPLEX LOAD(2*LC+LE)
DIMENSION WGHT(2*LC+LE)
```

3) Addition of caps to an open BOT with wires

```
COMPLEX PI((LS*KMODE+LW+NJ)^2),Q((LS*KMODE+LW+NJ)*(2*LC+LE)),
   R((LS*KMODE+LW+NJ)*(2*LC+LE)),S((2*LC+LE)^2),
   YI(max(LS*LS,(LW+NJ)^2,(2*LC+LE)^2))
COMPLEX W1(max(LS*KMODE+LW+NJ,2*LC+LE)),W2(2*LC+LE)
COMPLEX LOAD(2*LC+LE)
DIMENSION WGHT(2*LC+LE)
```

4) Addition of wires to a BOT with caps

```
COMPLEX PI((LS*KMODE+2*LC+LE)^2),Q((LS*KMODE+2*LC+LE)*(LW+NJ)),
   R((LS*KMODE+2*LC+LE)*(LW+NJ)),S((LW+NJ)^2),
   YI(max(LS*LS,(LW+NJ)^2,(2*LC+LE)^2)
COMPLEX W1(max(LS*KMODE+2*LC+LE,LW+NJ)),W2(LW+NJ)
COMPLEX LOAD(1)
DIMENSION WGHT(1)
```

BOTAC Minimum Dimensions

```
COMPLEX Y(MAX(LS*LS,(LW+NJ)^2,(2*LC+LE)^2))
COMPLEX TAB(NSA*NSA),ZAB(NSA*NSA),WAB(NJ*NJ)
```

BOTRA Minimum Dimensions

```
COMPLEX VS(LS),VW(LW+NJ)
COMPLEX GT(NT),GP(NT)
COMPLEX CB(LS*KMODE),CW(LW+NJ),CC(2*LC+LE)
COMPLEX Y(max(LS*LS,(LW+NJ)^2,(2*LC+LE)^2)
COMPLEX RBT(LS),RBP(LS),RWT(LW+NJ),RWP(LW+NJ),RCT(2*LC+LE),RCP(2*LC+LE)
DIMENSION THR(NT),PHIR(NT)
DIMENSION ANG(NANG),IPLANE(NANG),ANG1(NANG),ANG2(NANG)
SUBROUTINE VWIRE
DIMENSION IW(NWJV)
COMPLEX EW(NWJV)
SUBROUTINE NEARB
COMPLEX GT(NP-1),GZ(NP-1),G1T(NP-1),G1Z(NP-1),H1T(NP-1)
```

BOTSCM Minimum Dimensions

```
COMPLEX STT(NT),SPP(NT),STP(NT),SPT(NT)
COMPLEX CBT(LS),CBP(LS),CWT(LW+NJ),CWP(LW+NJ),CCT(2*LC+LE),CCP(2*LC+LE)
COMPLEX Y(max(LS*LS,(LW+NJ)^2,(2*LC+LE)^2)
COMPLEX RBT(NT*LS),RBP(NT*LS),RWT(NT*(LW+NJ)),RWP(NT*(LW+NJ)),
COMPLEX RCT(NT*(2*LC+LE)),RCP(NT*(2*LC+LE)
DIMENSION THS(NT),PHIS(NT)
DIMENSION ANG(NANG),IPLANE(NANG),ANG1(NANG),ANG2(NANG)
```

BOTSCB Minimum Dimensions

```
COMPLEX STT(NT),SPP(NT),STP(NT),SPT(NT)
COMPLEX CBT(LS*KMODE),CBP(LS*KMODE),CWT(LW+NJ),CWP(LW+NJ),CCT(2*LC+LE),
   CCP(2*LC+LE)
COMPLEX Y(max(LS*LS,(LW+NJ)^2,(2*LC+LE)^2)
COMPLEX RBT(LS),RBP(LS),RWT(LW+NJ),RWP(LW+NJ),RCT(2*LC+LE),RCP(2*LC+LE)
DIMENSION THS(NT),PHIS(NT)
DIMENSION ANG(NANG),IPLANE(NANG),ANG1(NANG),ANG2(NANG)
SUBROUTINE NEARB
COMPLEX GT(NP-1),GZ(NP-1),G1T(NP-1),G1Z(NP-1),H1T(NP-1)
```

2.6 Sample Problems

In this section, four sample problems are considered to illustrate the use of the MM/BOT algorithm. Sample Problem 1 exercises all main-line programs given in Figure 1 for BOTs having aperture (slot) antennas. The coordinate generation and specification of antenna location and feed are demonstrated. The inputs, outputs, and selected intermediate results are reproduced here in detail to provide a check case for the proper functioning of the codes. Problem 2 demonstrates the radiation analysis for a monopole antenna attached to a BOT. Inclusion of the junction effects exercises the junction-related parts of the impedance generating routines together with those for the wire representation of the monopole. The second and third parts of Problem 2 demonstrate the analysis for two monopoles, one active and the other passive, and a loop antenna. In Problem 3, the radiation, near-field, and coupling analyses are carried out for an active and passive monopole mounted on the trailing end of an asymmetric wing section. Problem 4 utilizes the scattering analysis routines for a closed cylindrical body. In this example, the procedures are demonstrated for inclusion of the edge transition region between the caps and the BOT surface.

2.6.1 Problem 1: Aperture Antenna on BOT

Consider a right-circular cylinder of 2.76λ length and 0.216λ radius with an embedded ϕ-polarized aperture antenna at $\phi = 90^\circ$. The aperture is fed uniformly, subtends a 45° opening, and is 2.07λ long in the axial direction (see Figure 5a). For simplicity, consider that the BOT is uncapped. (The radiation pattern for the capped body is substantially the same as for the present case.)

a) Calculate the power gain patterns in the horizontal ($\phi = 0, 180^\circ$) plane and the roll ($\theta = \pm 90^\circ$) planes in the θ and ϕ polarizations.

b) Compute the currents on the cylinder surface.

Solution -- The calculations were carried out at 10 MHz ($\lambda = 30$ m), using four modes (NMODE=4) to represent the BOT currents. The cylinder was represented by NP=17 points around the circumference.

BOTSEG was executed in a time-share mode (Figure 5b) in order to obtain the BOT generating curve. Figure 5c lists the input data used to execute the programs BOTZSS and BOTRA. For reference, the variables of the data set are

labeled. The aperture coincided with the second triangle function (IS = 2), and only one triangle function was used to span the aperture (NSA = 1). If a nonuniform aperture excitation is desired, then more triangle functions should be used to span the aperture, each with a different E_o. BOTINV was executed using NMODE=4, NBAND=14, and zero surface impedance loading.

Partial outputs from BOTZSS, BOTINV, and BOTRA are shown in Figures 6, 7, and 8, respectively. The radiation power gain for the slotted cylinder for the vertical plane normalized to an isotropic radiator is summarized in Figure 8a. (The comparison of these results with the MM/BOR analysis is given in Figure 8 of Volume I.) Partial output of the currents on the cylinder is plotted in Figure 8b.

The foregoing calculations were carried out at 10 MHz. If the dimensions of the body (BOT) and the antenna are given initially in terms of wavelength, any convenient frequency can be chosen in the setup procedure for carrying out the computations. If the data are to be compared with range measurements at a given frequency, for ease of data interpretation, the calculations also are done at that frequency.

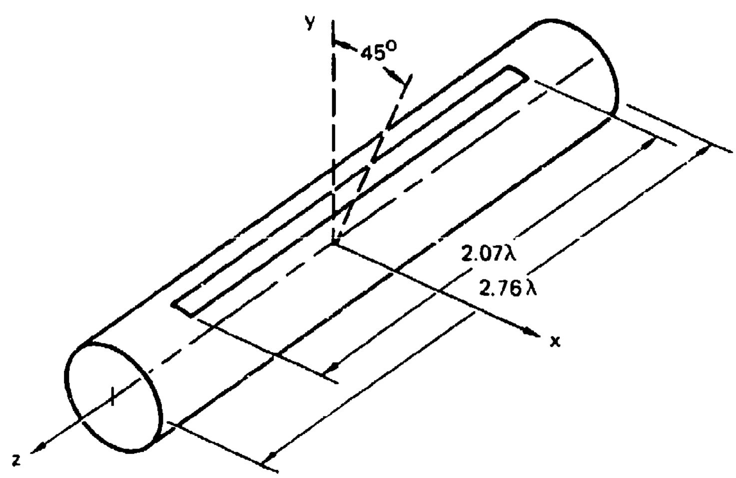


Figure 5a. Slotted cylinder for Problem 1.

```
RNH BOTSEG
? 3 17                                    (2I3)
? 0.0        0.0      6.48      0.0  }
?12.96       0.0      6.48      0.0  }   (4E10.4)
? 0.0        0.0
```

PERIMETER = 40.7150

NP = 17

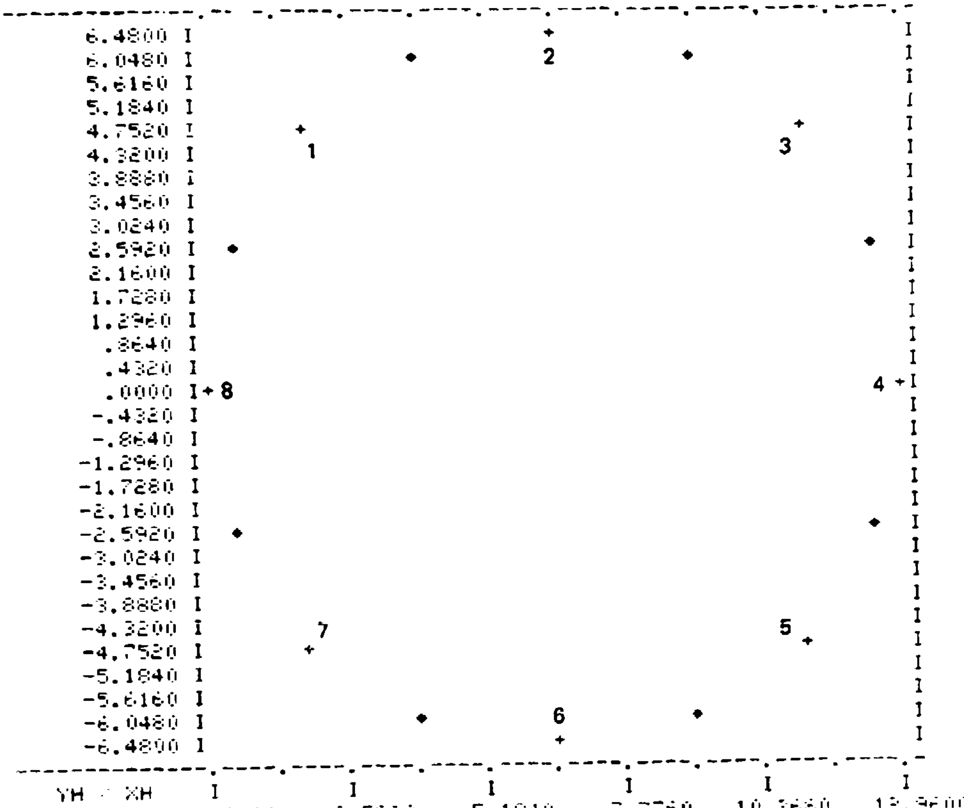
YH

0.0000	2.4798	4.5821	5.9867	6.4800	5.9867	4.5821	2.4798	0.0000	−2.4798
−4.5821	−5.9867	−6.4800	−5.9867	−4.5821	−2.4798	0.0000			

XH

0.0000	.4933	1.8979	4.0002	6.4800	8.9598	11.0621	12.4667	12.9600	12.4667
11.0621	8.9598	6.4800	4.0002	1.8979	.4933	0.0000			

BODY COORDINATES, + INDICATES TRIANGLE PEAK



STOP

Figure 5b. Execution of BOTSEG for Problem 1, with triangle functions numbered on the plot.

```
 .2094397E+00 BK
 4 20 14              NMODE, NPT, NBAND
17                    NP
  0.0000   2.4796   4.5821   5.9867   6.4800   5.9867   4.5821   2.4799   -.0000  -2.4798 YB
 -4.5821  -5.9867  -6.4800  -5.9867  -4.5821  -2.4799   0.0000                              BOT data set
  0.0000    .4933   1.8979   4.0002   6.4800   8.9599  11.0621  12.4667  12.9600  12.4667 XB
 11.0621   8.9596   6.4800   4.0002   1.8979    .4933   0.0000
 41.4            BL
  0    0    0    No caps
  0    0    0    No wires
  1                   NSA
        2             IS
-31.0590              ZO
 31.0500              Z1     Slot antenna data set
  1.0000     .0000    EO
  1.0000              TEXC
   .0000              ZEXC
 4  37                                      NANG, NT
   90.0       0.0     -90.0      90.0       ANG
      1         1         1         2       IPLANE     Radiation angles
    0.0       0.0       0.0     -90.0       ANG1
  180.0     180.0     180.0      90.0       ANG2
 0      NTEST
```

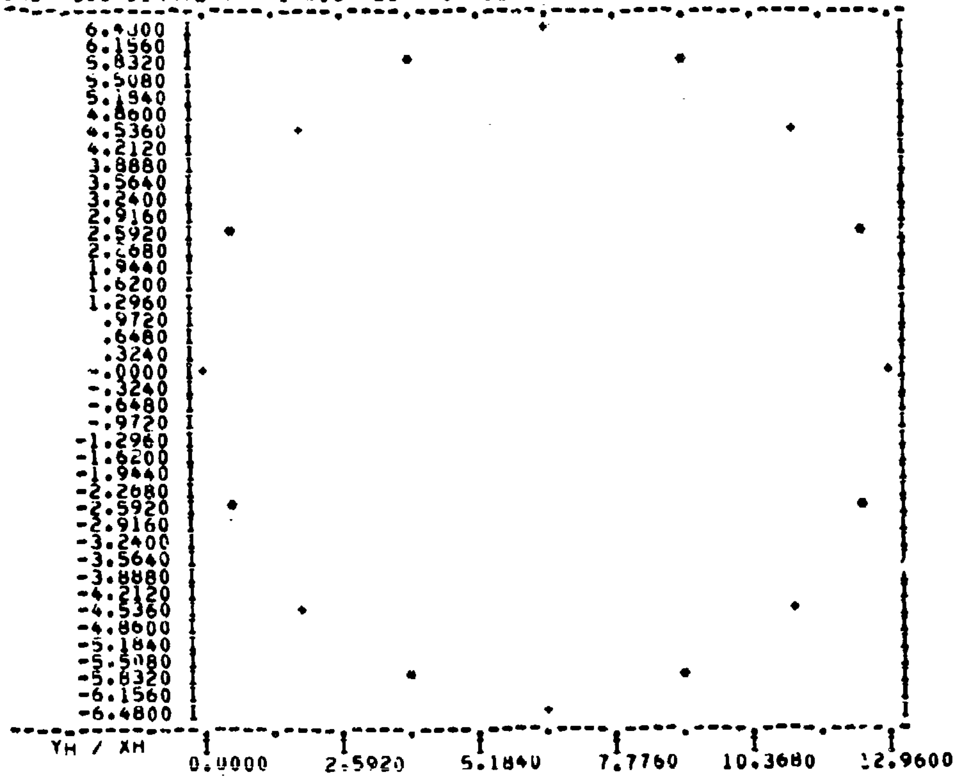
Figure 5c. Input data for execution of programs used in Problem 1.

```
      BK
  .2094397E+00
    NMODE     NPT       NBAND       NP
      4        20         14        17

YB
 0.0000   2.4798   4.5821   5.9867   6.4800   5.9867   4.5821   2.4798   0.0000  -2.4798
-4.5821  -5.9867  -6.4800  -5.9867  -4.5821  -2.4798   0.0000

XB
 0.0000    .4933   1.8979   4.0002   6.4800   8.9598  11.0621  12.4667  12.9600  12.4667
11.0621   8.9598   6.4800   4.0002   1.8979    .4933   0.0000
```

BODY COORDINATES, + INDICATES TRIANGLE PEAK




```
HALF-LENGTH OF BOT =       41.4000

BOT GENERATING CURVE IS CLOSED.  NP =  19

BOT GENERATING CURVE HAS UNIFORM SEGMENTATION
```

Figure 6a. Partial output of BOTZSS for Problem 1.

N= 0 M= 0

NUMBER OF INTEGRATIONS AND AVERAGE NUMBER OF POINTS PER INTEGRATION (SELF AND NON-SELF TERMS, RESPECTIVELY)
1 65.0 151 27.6

Z S(T) - S(T)

.1727E+05	-.4749E+05	.1417E+05	.2974E+05	8286.	.1597E+05
8223.	.1478E+05	8286.	.1597E+05	.1417E+05	.2974E+05
.1417E+05	.2974E+05	.1727E+05	-.4749E+05	.1417E+05	.2974E+05
9471.	.1553E+05	8223.	.1478E+05	8286.	.1597E+05
8286.	.1597E+05	.1417E+05	.2974E+05	.1727E+05	-.4749E+05
8223.	.1478E+05	9471.	.1553E+05	8223.	.1478E+05
8223.	.1478E+05	8286.	.1597E+05	.1417E+05	.2974E+05
8286.	.1597E+05	8223.	.1478E+05	9471.	.1553E+05
9471.	.1553E+05	8223.	.1478E+05	8286.	.1597E+05
.1417E+05	.2974E+05	8286.	.1597E+05	8223.	.1478E+05
8223.	.1478E+05	9471.	.1553E+05	8223.	.1478E+05
.1727E+05	-.4749E+05	.1417E+05	.2974E+05	8286.	.1597E+05
8286.	.1597E+05	8223.	.1478E+05	9471.	.1553E+05
.1417E+05	.2974E+05	.1727E+05	-.4749E+05	.1417E+05	.2974E+05
.1417E+05	.2974E+05	8286.	.1597E+05	8223.	.1478E+05
8286.	.1597E+05	.1417E+05	.2974E+05	.1727E+05	-.4749E+05

8223.	.1478E+05	9471.	.1553E+05
8286.	.1597E+05	8223.	.1478E+05
.1417E+05	.2974E+05	8286.	.1597E+05
.1727E+05	-.4749E+05	.1417E+05	.2974E+05
.1417E+05	.2974E+05	.1727E+05	-.4749E+05
8286.	.1597E+05	.1417E+05	.2974E+05
8223.	.1478E+05	8286.	.1597E+05
9471.	.1553E+05	8223.	.1478E+05

$Z^{sstt}_{0,0}$

Z S(Z) - S(T)

0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.

0.	0.	0.	0.
0.	0.	0.	0.
0.	0.	0.	0.
0.	0.	0.	0.
0.	0.	0.	0.
0.	0.	0.	0.
0.	0.	0.	0.
0.	0.	0.	0.

$Z^{sszt}_{0,0}$

Z S(T) - S(Z)

0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.

0.	0.	0.	0.
0.	0.	0.	0.
0.	0.	0.	0.
0.	0.	0.	0.
0.	0.	0.	0.
0.	0.	0.	0.
0.	0.	0.	0.
0.	0.	0.	0.

$Z^{sstz}_{0,0}$

Z S(Z) - S(Z)

1.000	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	1.000	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	1.000	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
1.000	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	1.000	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	1.000	0.

0.	0.	0.	0.
0.	0.	0.	0.
0.	0.	0.	0.
1.000	0.	0.	0.
0.	0.	1.000	0.
0.	0.	0.	0.
0.	0.	0.	0.
0.	0.	0.	0.

Identity matrix

Figure 6a. Continued.

```
MK  1  NK  1
NUMBER OF INTEGRATIONS AND AVERAGE NUMBER OF POINTS PER INTEGRATION (SELF AND NON-SELF TERMS, RESPECTIVELY)
      2   65.0            302   31.9

Z S(T) = S(T)
 .1929E+05 -.4527E+05  .1514E+05  .3061E+05  7100.      .1618E+05
 5449.      .1567E+05  7100.      .1618E+05  .1514E+05  .3061E+05
 .1514E+05  .3061E+05  .1929E+05 -.4527E+05  .1514E+05  .3061E+05
 6198.      .1709E+05  5449.      .1567E+05  7100.      .1618E+05
 7100.      .1618E+05  .1514E+05  .3061E+05  .1929E+05 -.4527E+05
 5449.      .1567E+05  6198.      .1709E+05  5449.      .1567E+05
 5449.      .1567E+05  7100.      .1618E+05  .1514E+05  .3061E+05
 7100.      .1618E+05  5449.      .1567E+05  6198.      .1709E+05
 6198.      .1709E+05  5449.      .1567E+05  7100.      .1618E+05
 .1514E+05  .3061E+05  7100.      .1618E+05  5449.      .1567E+05
 5449.      .1567E+05  6198.      .1709E+05  5449.      .1567E+05
 .1929E+05 -.4527E+05  .1514E+05  .3061E+05  7100.      .1618E+05
 7100.      .1618E+05  5449.      .1567E+05  6198.      .1709E+05
 .1514E+05  .3061E+05  .1929E+05 -.4527E+05  .1514E+05  .3061E+05
 .1514E+05  .3061E+05  7100.      .1618E+05  5449.      .1567E+05
 7100.      .1618E+05  .1514E+05  .3061E+05  .1929E+05 -.4527E+05

 5449.      .1567E+05  6198.      .1709E+05
 7100.      .1618E+05  5449.      .1567E+05
 .1514E+05  .3061E+05  7100.      .1618E+05
 .1929E+05 -.4527E+05  .1514E+05  .3061E+05
 .1514E+05  .3061E+05  .1927E+05 -.4527E+05
 7100.      .1618E+05  .1514E+05  .3061E+05
 5449.      .1567E+05  7100.      .1618E+05
 6198.      .1709E+05  5449.      .1567E+05
```

$Z^{SSTT}_{1,1}$

```
Z S(Z) = S(T)
 .1009E-09 -.1960E-09  .1149E+05 -4314.      3359.     -4840.
-321.0      2695.     -3359.      4840.     -.1149E+05  4314.
-.1149E+05  4314.      .1319E-09 -.3336E-[illegible]  .1149E+05 -4314.
-.2715E-10 -.2728E-11 -320.9      2695.     -3359.      4840.
-3359.      4840.     -.1149E+05  4314.      .5431E-10 -.1435E-09
 321.0     -2695.     -.2909E-10 -.1743E-10 -321.0      2695.
-320.9      2695.     -3359.      4840.     -.1149E+05  4314.
 3359.     -4840.      320.9     -2695.     -.3605E-10  .4364E-11
-.9504E-10  .1094E-10 -321.0      2695.     -3359.      4840.
 .1149E+05 -4314.      3359.     -4840.      321.0     -2695.
 320.9     -2695.     -.1047E-09 -.4213E-11 -320.9      2695.
 .1474E-09 -.2134E-09  .1149E+05 -4314.      3359.     -4840.
 3359.     -4840.      321.0     -2695.     -.1804E-09 -.7507E-10
-.1149E+05  4314.      .1629E-09 -.2056E-09  .1149E+05 -4314.
-.1149E+05  4314.      3359.     -4840.      320.9     -2695.
-3359.      4840.     -.1149E+05  4314.      .1397E-09 -.2636E-09

 321.0     -2695.     -.1940E-11  .6619E-10
 3359.     -4840.      320.9     -2695.
 .1149E+05 -4314.      3359.     -4840.
 .1397E-09 -.2328E-09  .1149E+05 -4314.
-.1149E+05  4314.      .1164E-09 -.2599E-09
-3359.      4840.     -.1149E+05  4314.
-321.0      2695.     -3359.      4840.
-.1300E-09 -.1115E-10 -320.9      2695.
```

$Z^{SSZT}_{1,1}$

```
Z S(T) = S(Z)
-.5431E-10  .6207E-10  .1149E+05 -4314.      3359.     -4830.
-320.9      2695.     -3359.      4840.     -.1149E+05  4314.
-.1149E+05  4314.     -.3310E-10  .6534E-10  .1149E+05 -4314.
 .1047E-09  .4213E-11 -321.0      2695.     -3359.      4840.
-3359.      4840.     -.1149E+05  4314.     -.5431E-10  .2715E-10
 320.9     -2695.      .1804E-09  .7507E-10 -320.9      2695.
 321.0      2695.     -3359.      4840.     -.1149E+05  4314.
 3359.     -4840.      321.0     -2695.      .1300E-09  .1115E-10
 .1940E-11 -.6019E-10 -320.9      2695.     -3359.      4840.
 .1149E+05 -4314.      3359.     -4840.      320.9     -2695.
 321.0     -2695.      .2715E-10 -.2728E-11 -321.0      2695.
-.1009E-09  .1491E-10  .1149E+05 -4314.      3359.     -4840.
 3359.     -4840.      320.9     -2695.      .2909E-10  .1743E-10
-.1149E+05  4314.     -.1319E-09  .3336E-10  .1149E+05 -4314.
-.1149E+05  4314.      3359.     -4840.      321.0     -2695.
-3359.      4840.     -.1149E+05  4314.     -.1088E-09  .5431E-10

 320.9     -2695.      .9504E-10 -.1094E-10
 3359.     -4840.      321.0     -2695.
 .1149E+05 -43.4.      3359.     -4840.
-.1164E-09  .3163E-10  .1149E+05 -4314.
-.1149E+05  4314      -.6983E-10  .8922E-10
-3359.      4840.     -.1149E+05  4314.
-320.9      2695.     -3359.      4840.
 .3005E-10 -.4364E-11 -321.0      2695.
```

$Z^{SSTZ}_{1,1}$

```
Z S(Z) = S(Z)
 .7193E+05 -.5114E+05  .5719E+05  6785.      .2728E+05 -.3218E+05
 3938.     -.3904E+05  .2728E+05 -.3218E+05  .5719E+05  6785.
 .5719E+05  6785.      .7193E+05 -.5114E+05  .5719E+05  6785.
-4023.     -.3850E+05  3938.     -.3904E+05  .2728E+05 -.3218E+05
 .2728E+05 -.3218E+05  .5719E+05  6785.      .7193E+05 -.5114E+05
 3938.     -.3904E+05 -4023.     -.3850E+05  3938.     -.3904E+05
 3938.     -.3904E+05  .2728E+05 -.3218E+05  .5719E+05  6785.
 .2728E+05 -.3218E+05  3938.     -.3904E+05 -4023.     -.3850E+05
-4023.     -.3850E+05  3938.     -.3904E+05  .2728E+05 -.3218E+05
 .5719E+05  6785.      .2728E+05 -.3218E+05  3938.     -.3904E+05
 3938.     -.3904E+05 -4023.     -.3850E+05  3938.     -.3904E+05
 .7193E+05 -.5114E+05  .5719E+05  6785.      .2728E+05 -.3218E+05
 .2728E+05 -.3218E+05  3938.     -.3904E+05 -4023.     -.3850E+05
 .5719E+05  6785.      .7193E+05 -.5114E+05  .5719E+05  6785.
 .5719E+05  6785.      .2728E+05 -.3218E+05  3938.     -.3904E+05
 .2728E+05 -.3218E+05  .5719E+05  6785.      .7193E+05  .5114E+05

 3938.     -.3904E+05 -4023.     -.3850E+05
 .2728E+05 -.3218E+05  3938.     -.3904E+05
 .5719E+05  6785.      .2728E+05 -.3218E+05
 .7193E+05  .5114E+05  .5710E+05  6785.
 .5719E+05  6785.      .7193E+05  .5114E+05
 .2728E+05 -.3218E+05  .5719E+05  6785.
 3938.     -.3904E+05  .2728E+05 -.3218E+05
-4022.     -.3850E+05  3938.     -.3904E+05
```

$Z^{SSZZ}_{1,1}$

Figure 6a. Concluded.

```
M= 2  N= 1
NUMBER OF INTEGRATIONS AND AVERAGE NUMBER OF POINTS PER INTEGRATION (SELF AND NON-SELF TERMS, RESPECTIVELY)
      2   97.0          302   31.9
```

```
Z S(T) - S(T)
  830.6      -2280.       537.2       -582.8       397.6        674.0
  890.6       1650.       397.6        674.0       537.2       -582.8
  537.2      -582.8       830.6       -2280.       537.2       -582.8
  1255.       2048.       890.6        1650.       397.6        674.0
  397.6       674.0       537.2       -582.8       830.6       -2280.
  890.6       1650.       1255.        2048.       890.6        1650.
  890.6       1650.       397.6        674.0       537.2       -582.8
  397.6       674.0       890.6        1650.       1255.        2048.
  1255.       2048.       890.6        1650.       397.6        674.0
  537.2      -582.8       397.6        674.0       890.6        1650.
  890.6       1650.       1255.        2048.       890.6        1650.
  830.6      -2280.       537.2       -582.8       397.6        674.0
  397.6       674.0       890.6        1650.       1255.        2048.
  537.2      -582.8       830.6       -2280.       537.2       -582.8
  537.2      -582.8       397.6        674.0       890.6        1650.
  397.6       674.0       537.2       -582.8       830.6       -2280.

  890.6       1650.       1255.        2048.
  397.6       674.0       890.6        1650.
  537.2      -582.8       397.6        674.0
  830.6      -2280.       537.2       -582.8
  537.2      -582.8       830.6       -2280.
  397.6       674.0       537.2       -582.8
  890.6       1650.       397.6        674.0
  1255.       2048.       890.6        1650.
```

$Z^{SSTT}_{2,1}$

```
Z S(Z) - S(T)
 -.1109E-10  -.2812E-10   662.3       -547.8       304.5       -695.9
 -23.75       433.7      -304.5        695.9      -662.3        547.8
 -662.4       547.8      -.1346E-10  -.1390E-10    662.4       -547.8
 -.1018E-10   .1607E-11  -23.75        433.7      -304.5        695.9
 -304.5       695.9      -662.3        547.8      -.1267E-10  -.2136E-10
  23.75      -433.7      -.1115E-10  -.2102E-11   -23.75        433.7
 -23.75       433.7      -304.5        695.9      -662.4        547.8
  304.5      -695.9       23.75       -433.7      -.4364E-11   .3637E-11
 -.2279E-10   .1091E-10  -23.75        433.7      -304.5        695.9
  662.3      -547.8       304.5       -695.9       23.75       -433.7
  23.75      -433.7      -.1358E-10   .9941E-11   -23.75        433.7
 -.1606E-10  -.2909E-10   662.4       -547.8       304.5       -695.9
  304.5      -695.9       23.75       -433.7      -.2667E-10  -.1607E-11
 -662.3       547.8      -.1315E-10  -.3103E-10    662.3       -547.8
  662.4      -547.8       304.5       -695.9       23.75       -433.7
 -304.5       695.9      -662.4        547.8      -.1200E-10  -.3006E-10

  23.75      -433.7      -.5334E-11    .1333E-10
  304.5      -695.9       23.75       -433.7
  662.3      -547.8       304.5       -695.9
 -.1346E-10  -.2618E-10   662.4       -547.8
 -662.3       547.8      -.1273E-10   -.3879E-10
 -304.5       695.9      -662.4        547.8
 -23.75       433.7      -304.5        695.9
 -.3346E-10   .8001E-11  -23.75        433.7
```

$Z^{SSZT}_{2,1}$

```
Z S(T) - S(Z)
 -.6364E-12   .2909E-11   331.2       -273.9       152.2       -348.0
 -11.87       216.8      -152.2        348.0      -331.2        273.9
 -331.2       273.9      -.2465E-12    .1940E-11   331.2       -273.9
  .6709E-11  -.4970E-11  -11.88        216.8      -152.2        348.0
 -152.2       348.0      -331.2        273.9       .7577E-12    .3879E-11
  11.87      -216.8       .1353E-10    .8400E-12  -11.87        216.8
 -11.88       216.8      -152.2        348.0      -331.2        273.9
  152.2      -348.0       11.88       -216.8       .1873E-10  -.4000E-11
  .2667E-11  -.6067E-11  -11.87        216.8      -152.2        348.0
  331.2      -273.9       152.2       -348.0       11.87       -216.8
  11.88      -216.8       .5091E-11  -.8400E-12  -11.88        216.8
 -.1849E-12   .8243E-11   331.2       -273.9       152.2       -348.0
  152.2      -348.0       11.87       -216.8       .5576E-11    .1091E-11
 -331.2       273.9       .1272E-12    .8243E-11   331.2       -273.9
  331.2      -273.9       152.2       -348.0       11.88       -216.8
 -152.2       348.0      -331.2        273.9      -.1818E-12    .5819E-11

  11.87      -216.8       .1140E-10   -.5455E-11
  152.2      -348.0       11.88       -216.8
  331.2      -273.9       152.2       -348.0
 -.1818E-12   .5334E-11   331.2       -273.9
 -331.2       273.9      -.9092E-12    .4364E-11
 -152.2       348.0      -331.2        273.9
 -11.87       216.8      -152.2        348.0
  .2182E-11  -.1818E-11  -11.88        216.8
```

$Z^{SSTZ}_{2,1}$

```
Z S(Z) - S(Z)
 -.3847E+05  -.2585E+05  -.3006E+05   -2271.      -.1313E+05   .1797E+05
 -158.6       .2088E+05  -.1313E+05    .1797E+05  -.3006E+05   -2271.
 -.3006E+05  -2271.      -.3847E+05   -.2585E+05  -.3006E+05   -2271.
  4190.       .2024E+05  -158.6        .2088E+05  -.1313E+05   .1797E+05
 -.1313E+05   .1797E+05  -.3006E+05   -2271.      -.3847E+05  -.2585E+05
 -158.6       .2088E+05   4190.        .2024E+05  -158.6       .2088E+05
 -158.6       .2088E+05  -.1313E+05    .1797E+05  -.3006E+05   -2271.
 -.1313E+05   .1797E+05  -158.6        .2088E+05   4190.       .2024E+05
  4190.       .2024E+05  -158.6        .2088E+05  -.1313E+05   .1797E+05
 -.3006E+05  -2271.      -.1313E+05    .1797E+05  -158.6       .2088E+05
 -158.6       .2088E+05   4190.        .2024E+05  -158.6       .2088E+05
 -.3847E+05  -.2585E+05  -.3006E+05   -2271.      -.1313E+05   .1797E+05
 -.1313E+05   .1797E+05  -158.6        .2088E+05   4190.       .2024E+05
 -.3006E+05  -2271.      -.3847E+05   -.2585E+05  -.3006E+05   -2271.
 -.3006E+05  -2271.      -.1313E+05    .1797E+05  -158.6       .2088E+05
 -.1313E+05   .1797E+05  -.3006E+05   -2271.      -.3847E+05  -.2585E+05

 -158.6       .2088E+05   4190.        .2024E+05
 -.1313E+05   .1797E+05  -158.6        .2088E+05
 -.3006E+05  -2271.      -.1313E+05    .1797E+05
 -.3847E+05  -.2585E+05  -.3006E+05   -2271.
 -.3006E+05  -2271.      -.3847E+05   -.2585E+05
 -.1313E+05   .1797E+05  -.3006E+05   -2271.
 -158.6       .2088E+05  -.1313E+05    .1797E+05
  4190.       .2024E+05  -158.6        .2088E+05
```

$Z^{SSZZ}_{2,1}$

Figure 6b. Partial output of BOTZSS for Problem 1.

```
   NP        NMODE      NBAND
   19          4          14                 NMODE and NBAND are user specified
 1 AND 2 SURFACE IMPEDANCE LOADING (COMPLEX)

  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
                                                                                 Surface loadings are user specified
  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000

 THE MINIMUM BOTINV ARRAY DIMENSIONS FOR THIS PROBLEM ARE AS FOLLOWS:
       Z          Z1      LOADWGHT      NZ         L4
     12544        256        16          0         112

FULL MATRIX INVERSION

 M= -3  N= -3
Y1
  .1444E-05  .4467E-06  .1037E-05 -.2842E-05 -.7098E-08 -.2277E-06 -.7496E-06 -.3015E-05 -.1077E-05  .2733E-05
 -.7496E-06 -.3015E-05 -.7098E-08 -.2277E-06  .1037E-05 -.2842E-05
  .1037E-05 -.2842E-05  .1444E-05  .4467E-06  .1037E-05 -.2842E-05 -.7100E-08 -.2277E-06 -.7496E-06 -.3015E-05
 -.1077E-05  .2733E-06 -.7496E-06 -.3015E-05 -.7100E-08 -.2277E-06
 -.7098E-08 -.2277E-06  .1037E-05 -.2842E-05  .1444E-05  .4467E-06  .1037E-05 -.2842E-05 -.7098E-08 -.2277E-05
 -.7496E-06 -.3015E-05 -.1077E-05  .2733E-06 -.7496E-06 -.3015E-05
 -.7496E-06 -.3015E-05 -.7100E-08 -.2277E-06  .1037E-05 -.2842E-05  .1444E-05  .4467E-06  .1037E-05 -.2842E-05   Ysstt -3,-3
 -.7100E-08 -.2277E-06 -.7496E-06 -.3015E-05 -.1077E-05  .2733E-06
 -.1077E-05  .2733E-06 -.7496E-06 -.3015E-05 -.7098E-08 -.2277E-06  .1037E-05 -.2842E-05  .1444E-05  .4467E-05
  .1037E-05 -.2842E-05 -.7098E-08 -.2277E-06 -.7496E-06 -.3015E-05
 -.7496E-06 -.3015E-05 -.1077E-05  .2733E-06 -.7496E-06 -.3015E-05 -.7100E-08 -.2277E-06  .1037E-05 -.2842E-05
  .1444E-05  .4467E-06  .1037E-05 -.2842E-05 -.7100E-08 -.2277E-06
 -.7098E-08 -.2277E-06 -.7496E-06 -.3015E-05 -.1077E-05  .2733E-06 -.7496E-06 -.3015E-05 -.7098E-08 -.2277E-06
  .1037E-05 -.2842E-05  .1444E-05  .4467E-06  .1037E-05 -.2842E-05
  .1037E-05 -.2842E-05 -.7100E-08 -.2277E-06 -.7496E-06 -.3015E-05 -.1077E-05  .2733E-06 -.7496E-06 -.3015E-05
 -.7100E-08 -.2277E-06  .1037E-05 -.2842E-05  .1444E-05  .4467E-06
Y2
  .8995E-18 0.          .1412E-04 -.1327E-06 -.5746E-05 -.6188E-06  .4854E-05 -.4052E-06  .3795E-18 -.4337E-18
 -.4854E-05  .4052E-06  .5746E-05  .6188E-06 -.1412E-04 -.1327E-06
 -.1412E-04  .1327E-06  .7318E-18 -.6709E-18  .1412E-04 -.1327E-06 -.5746E-05 -.6188E-06  .4854E-05 -.4052E-06
  .6132E-18 -.8403E-18 -.4854E-05  .4052E-06  .5746E-05  .6188E-06
  .5746E-05  .6188E-06 -.1412E-04  .1327E-06  .6641E-18 -.3228E-17  .1412E-04 -.1327E-06 -.5746E-05 -.6188E-05
  .4854E-05 -.4052E-06  .9608E-18 -.3043E-17 -.4854E-05  .4052E-06
 -.4854E-05  .4052E-06  .5746E-05  .6188E-06 -.1412E-04  .1327E-06 -.8796E-18 -.8439E-18  .1412E-04 -.1327E-05
 -.5746E-05 -.6188E-06  .4854E-05 -.4052E-06 -.1511E-17 -.4320E-18
  .2082E-18  .2189E-17 -.4854E-05  .4052E-06  .5746E-05  .6188E-06 -.1412E-04  .1327E-06  .1166E-17  .2372E-17   Ysszt -3,-3
  .1412E-04 -.1327E-06 -.5746E-05 -.6188E-06  .4854E-05 -.4052E-06
  .4854E-05 -.4052E-06 -.5421E-19  .2032E-18 -.4854E-05  .4052E-06  .5746E-05  .6188E-06 -.1412E-04  .1327E-06
  .4337E-18  .5014E-18  .1412E-04 -.1327E-06 -.5746E-05 -.6188E-06
 -.5746E-05 -.6188E-06  .4854E-05 -.4052E-06  .1220E-17  .1050E-17 -.4854E-05  .4052E-06  .5746E-05  .6188E-05
 -.1412E-04  .1327E-06  .1437E-17  .1721E-17  .1412E-04 -.1327E-06
  .1412E-04 -.1327E-06 -.5746E-05 -.6188E-06  .4854E-05 -.4052E-06 -.1067E-17  .2287E-17 -.4854E-05  .4052E-06
  .5746E-05  .6188E-06 -.1412E-04  .1327E-06 -.2993E-18  .1104E-17
Y3
  .3551E-17 -.1579E-17  .1412E-04 -.1327E-06 -.5746E-05 -.6188E-06  .4854E-05 -.4052E-06 -.3849E-17  .2982E-18
 -.4854E-05  .4052E-06  .5746E-05  .6188E-06 -.1412E-04  .1327E-06
 -.1412E-04  .1327E-06 -.1545E-17  .6099E-19  .1412E-04 -.1327E-06 -.5746E-05 -.6188E-06  .4854E-05 -.4052E-06
  .1409E-17  .1977E-17 -.4854E-05  .4052E-06  .5746E-05  .6188E-06
  .5746E-05  .6188E-06 -.1412E-04  .1327E-06 -.2516E-18  .3228E-17  .1412E-04 -.1327E-06 -.5746E-05 -.6188E-05
  .4854E-05 -.4052E-06  .1419E-17 -.4701E-18 -.4854E-05  .4052E-06
 -.4854E-05  .4052E-06  .5746E-05  .6188E-06 -.1412E-04  .1327E-06 -.1979E-17 -.1518E-17  .1412E-04 -.1327E-05
 -.5746E-05 -.6188E-06  .4854E-05 -.4052E-06  .3957E-17  .4076E-18
  .3876E-17 -.9158E-18 -.4854E-05  .4052E-06  .5746E-05  .6188E-06 -.1412E-04  .1327E-06 -.3822E-17  .6099E-18   Ysstz -3,-3
  .1412E-04 -.1327E-06 -.5746E-05 -.6188E-06  .4854E-05 -.4052E-06
  .4854E-05 -.4052E-06 -.2667E-17  .7103E-18 -.4254E-05  .4052E-06  .5746E-05  .6188E-06 -.1412E-04  .1327E-06
  .1870E-17  .1199E-17  .1412E-04 -.1327E-06 -.5746E-05 -.6188E-06
 -.5746E-05 -.6188E-06  .4854E-05 -.4052E-06 -.9540E-18  .2759E-17 -.4854E-05  .4052E-06  .5746E-05  .6188E-05
 -.1412E-04  .1327E-06  .1652E-17 -.5522E-18  .1412E-04 -.1327E-06
  .1412E-04 -.1327E-06 -.5746E-05 -.6188E-06  .4854E-05 -.4052E-06 -.2575E-17 -.1667E-17 -.4854E-05  .4052E-05
  .5746E-05  .6188E-06 -.1412E-04  .1327E-06  .3578E-17  .5016E-18
Y4
  .4871E-05 -.6391E-04  .2663E-05  .6110E-04  .2511E-05 -.3157E-04  .7730E-06  .1728E-04  .1144E-05 -.1420E-04
  .7730E-06  .1728E-04  .2511E-05 -.3157E-04  .2663E-05  .6110E-04
  .2663E-05  .6110E-04  .4871E-05 -.6391E-04  .2663E-05  .6110E-04  .2510E-05 -.3157E-04  .7730E-06  .1728E-04
  .1144E-05 -.1420E-04  .7730E-06  .1728E-04  .2510E-05 -.3157E-04
  .2511E-05 -.3157E-04  .2663E-05  .6110E-04  .4871E-05 -.6391E-04  .2663E-05  .6110E-04  .2511E-05 -.3157E-04
  .7730E-06  .1728E-04  .1144E-05 -.1420E-04  .7730E-06  .1728E-04
  .7730E-06  .1728E-04  .2510E-05 -.3157E-04  .2663E-05  .6110E-04  .4871E-05 -.6391E-04  .2663E-05  .6110E-04
  .2510E-05 -.3157E-04  .7730E-06  .1728E-04  .1144E-05 -.1420E-04
  .1144E-05 -.1420E-04  .7730E-06  .1728E-04  .2511E-05 -.3157E-04  .2663E-05  .6110E-04  .4871E-05 -.6391E-04   Ysszz -3,-3
  .2663E-05  .6110E-04  .2511E-05 -.3157E-04  .7730E-06  .1728E-04
  .7730E-06  .1728E-04  .1144E-05 -.1420E-04  .7730E-06  .1728E-04  .2510E-05 -.3157E-04  .2663E-05  .6110E-04
  .4871E-05 -.6391E-04  .2663E-05  .6110E-04  .2510E-05 -.3157E-04
  .2511E-05 -.3157E-04  .7730E-06  .1728E-04  .1144E-05 -.1420E-04  .7730E-06  .1728E-04  .2511E-05 -.3157E-04
  .2663E-05  .6110E-04  .4871E-05 -.6391E-04  .2663E-05  .6110E-04
  .2663E-05  .6110E-04  .2510E-05 -.3157E-04  .7730E-06  .1728E-04  .1144E-05 -.1420E-04  .7730E-06  .1728E-04
  .2510E-05 -.3157E-04  .2663E-05  .6110E-04  .4871E-05 -.6391E-04
```

Figure 7. Partial output of BOTINV for Problem 1 (admittance matrices).

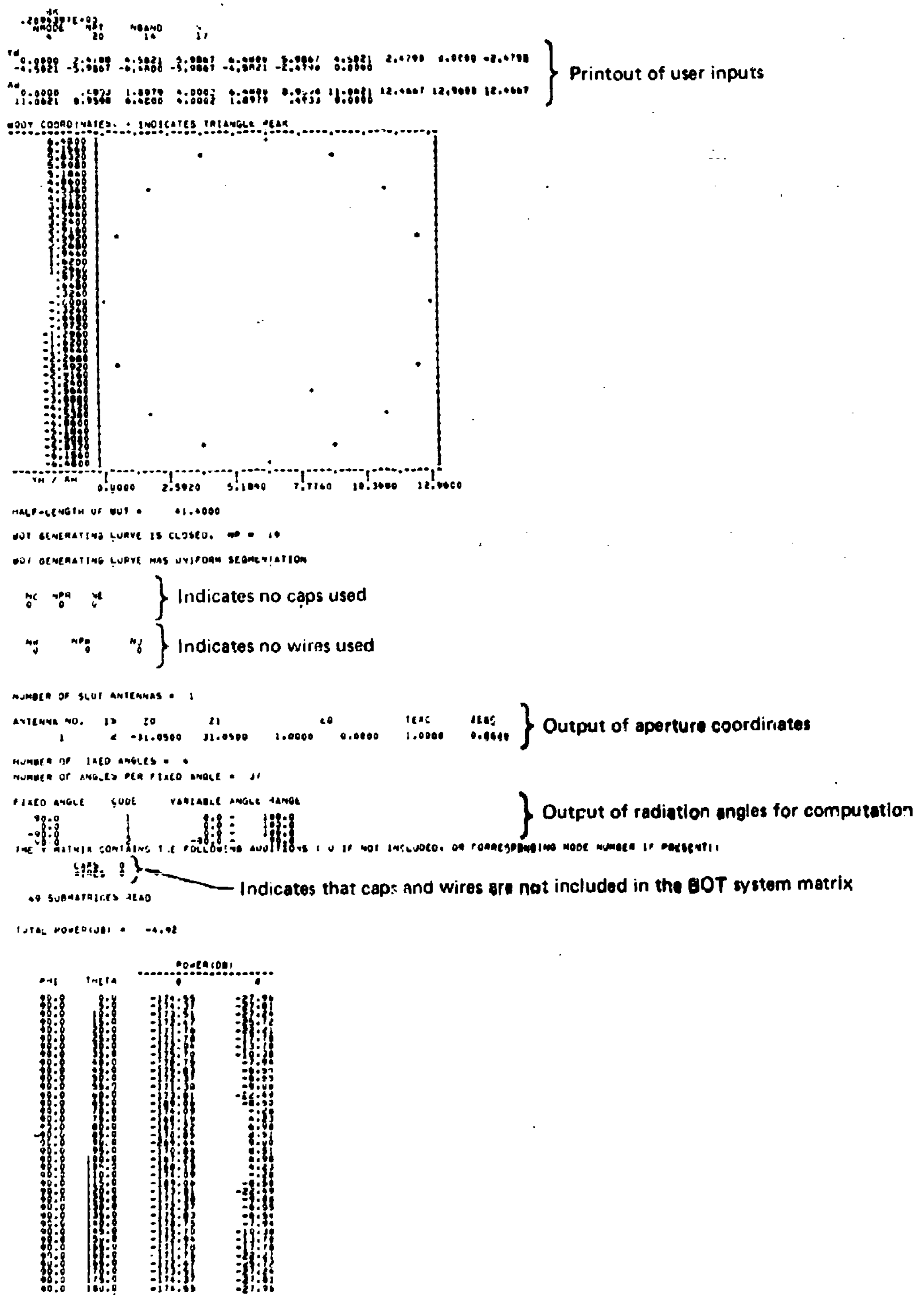
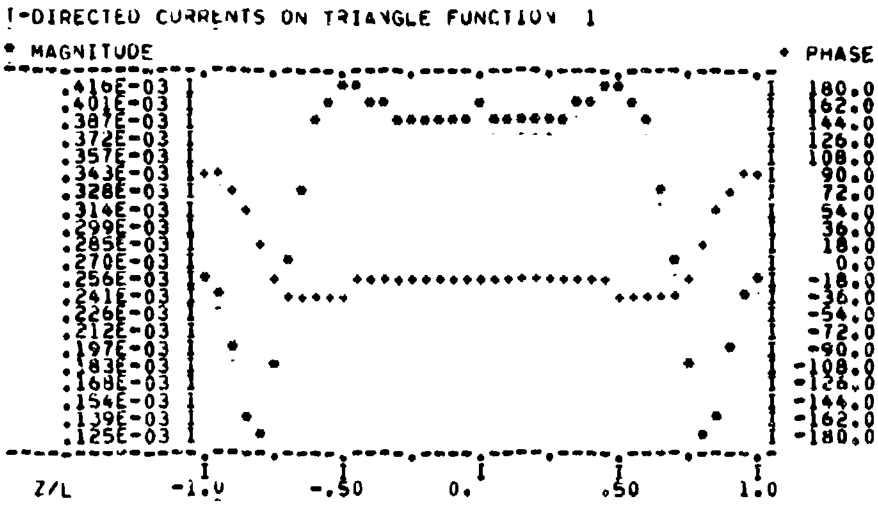


Figure 8a. Partial output of BOTRA for Problem 1.

```
BOT CURRENTS
T-DIRECTED CURRENTS FOR MODE -3
  .1534E-04  -.9441E-04        .1633E-04  -.4873E-04        .1534E-04  -.9441E-04        .4455E-05   .8158E-05
 -.5343E-05  -.1001E-03       -.1243E-04   .2530E-04       -.5343E-05  -.1001E-03        .4455E-05   .8158E-05
Z-DIRECTED CURRENTS FOR MODE -3
 -.5054E-03  -.2362E-05        .4084E-16  -.3455E-15        .5054E-03   .2362E-05       -.2558E-03  -.1721E-05
  .1723E-03   .4563E-05       -.6323E-17  -.3753E-15       -.1723E-03  -.4563E-05        .2558E-03   .1721E-05
T-DIRECTED CURRENTS FOR MODE -2
 -.8086E-04   .1405E-03       -.1003E-03  -.4286E-03       -.8086E-04   .1405E-03       -.2248E-04   .8900E-04
  .1832E-04   .1808E-03        .3406E-04   .1215E-03        .1832E-04   .1808E-03       -.2248E-04   .8900E-04
Z-DIRECTED CURRENTS FOR MODE -2
  .6445E-03  -.5445E-04       -.4766E-16  -.2368E-15       -.6445E-03   .5445E-04        .1986E-03   .6793E-04
 -.1122E-03   .2859E-04       -.4098E-16  -.2359E-15        .1122E-03  -.2859E-04       -.1985E-03  -.6793E-04
T-DIRECTED CURRENTS FOR MODE -1
  .1642E-03  -.9687E-04        .2369E-03   .1032E-02        .1642E-03  -.9687E-04        .1880E-04  -.2456E-03
 -.4021E-04  -.3148E-03       -.4437E-04  -.3016E-03       -.4021E-04  -.3148E-03        .1880E-04  -.2456E-03
Z-DIRECTED CURRENTS FOR MODE -1
 -.4366E-03   .5267E-04        .1458E-16   .5099E-16        .4366E-03  -.5267E-04       -.9185E-04  -.4238E-04
  .5281E-04  -.2597E-05        .3479E-16   .1157E-15       -.5281E-04   .2597E-05        .9185E-04   .4238E-04
T-DIRECTED CURRENTS FOR MODE  0
  .5521E-03  -.1452E-03        .8375E-03   .3894E-02        .5521E-03  -.1452E-03        .3742E-04  -.9149E-03
 -.9749E-04  -.1129E-02       -.5748E-04  -.1143E-02       -.9749E-04  -.1129E-02        .3742E-04  -.9149E-03
Z-DIRECTED CURRENTS FOR MODE  0
 0.           0.              0.          0.               0.          0.               0.          0.
 0.           0.              0.          0.               0.          0.               0.          0.
T-DIRECTED CURRENTS FOR MODE  1
  .1642E-03  -.9687E-04        .2369E-03   .1032E-02        .1642E-03  -.9687E-04        .1880E-04  -.2456E-03
 -.4021E-04  -.3148E-03       -.4437E-04  -.3016E-03       -.4021E-04  -.3148E-03        .1880E-04  -.2456E-03
Z-DIRECTED CURRENTS FOR MODE  1
  .4366E-03  -.5267E-04       -.8883E-17   .1204E-15       -.4366E-03   .5267E-04        .9185E-04   .4238E-04
 -.5281E-04   .2597E-05       -.1845E-16   .6239E-16        .5281E-04  -.2597E-05       -.9185E-04  -.4238E-04
T-DIRECTED CURRENTS FOR MODE  2
 -.8086E-04   .1405E-03       -.1003E-03  -.4286E-03       -.8086E-04   .1405E-03       -.2248E-04   .8900E-04
  .1832E-04   .1808E-03        .3406E-04   .1215E-03        .1832E-04   .1808E-03       -.2248E-04   .8900E-04
Z-DIRECTED CURRENTS FOR MODE  2
 -.6445E-03   .5445E-04       -.1233E-16  -.2560E-15        .6445E-03  -.5445E-04       -.1986E-03  -.6793E-04
  .1122E-03  -.2859E-04       -.3289E-16  -.1631E-15       -.1122E-03   .2859E-04        .1986E-03   .6793E-04
T-DIRECTED CURRENTS FOR MODE  3
  .1534E-04  -.9441E-04        .1633E-04  -.4873E-04        .1534E-04  -.9441E-04        .4455E-05   .8158E-05
 -.5343E-05  -.1001E-03       -.1243E-04   .2530E-04       -.5343E-05  -.1001E-03        .4455E-05   .8158E-05
Z-DIRECTED CURRENTS FOR MODE  3
  .5054E-03   .2362E-05       -.8520E-16  -.3579E-15       -.5054E-03  -.2362E-05        .2558E-03   .1721E-05
 -.1723E-03  -.4563E-05       -.8025E-16  -.2800E-15        .1723E-03   .4563E-05       -.2558E-03  -.1721E-05
```

Figure 8b. Output of BOT currents for Problem 1.



Axial distribution of currents on BOT along strip subtracted by triangle function 1.

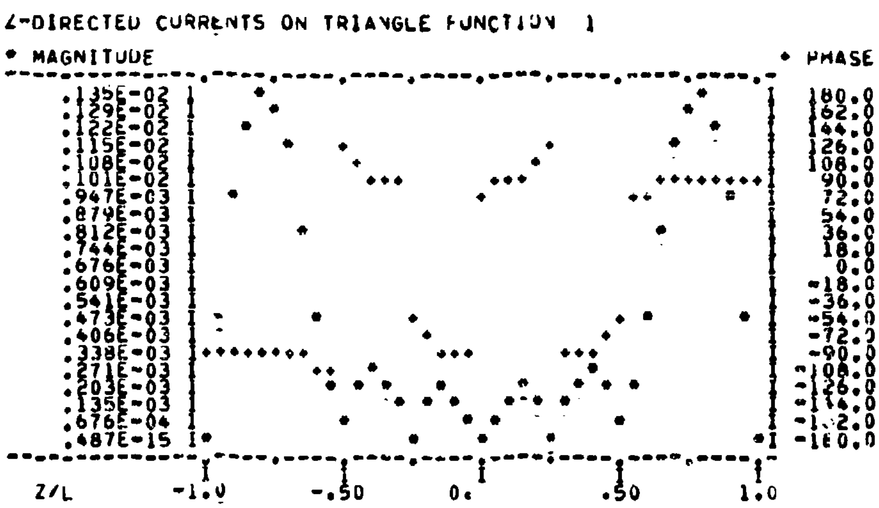
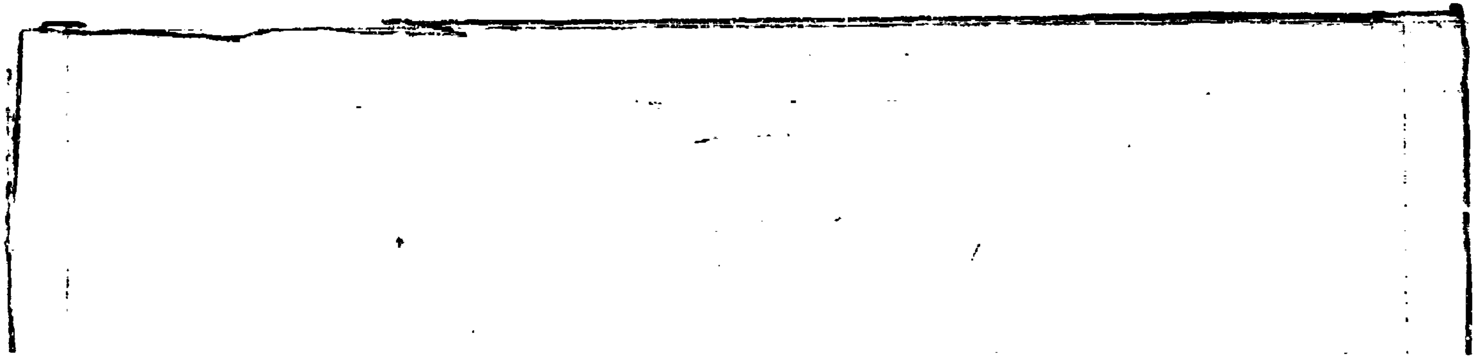


Figure 8b. Concluded.



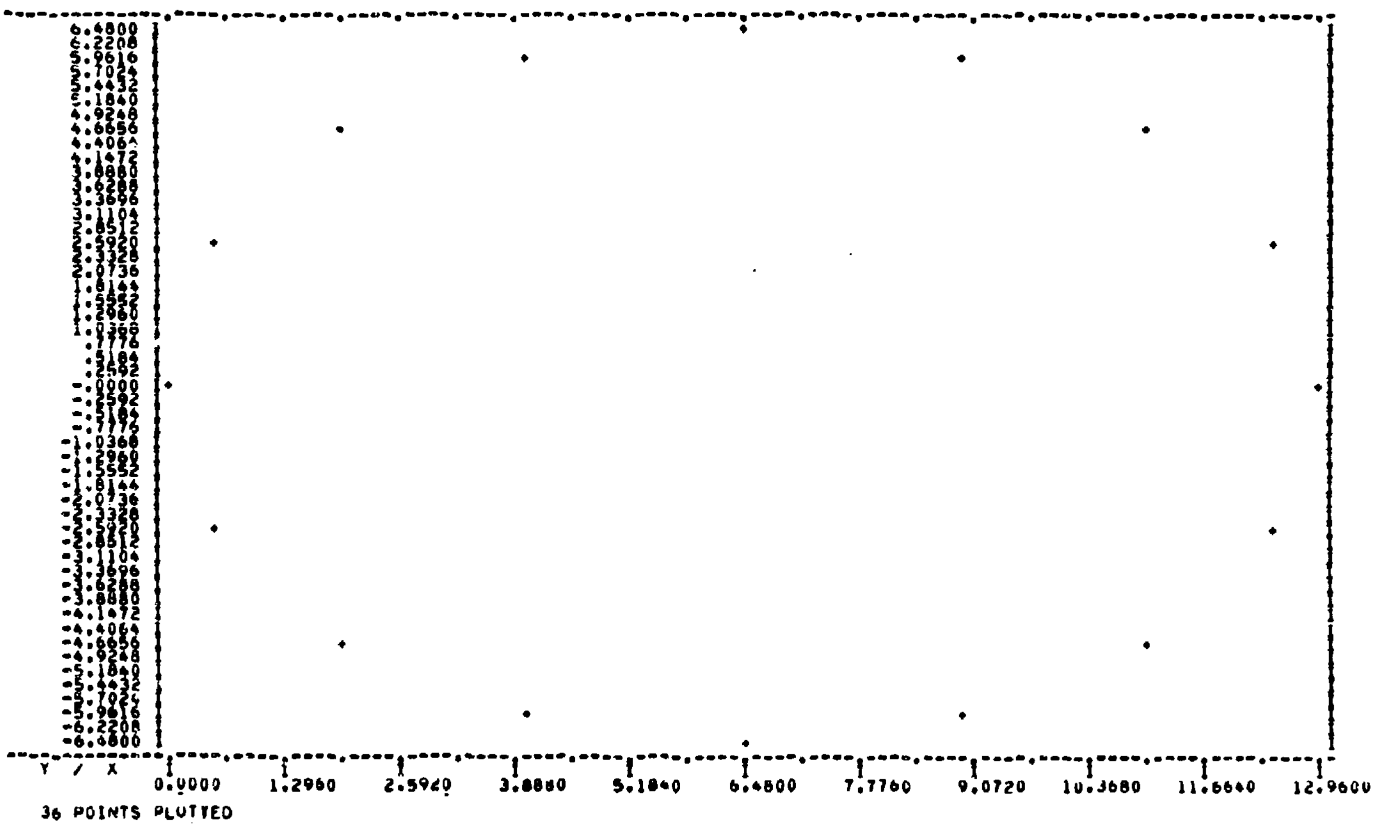


Figure 8c. Output of geometry for Problem 1.

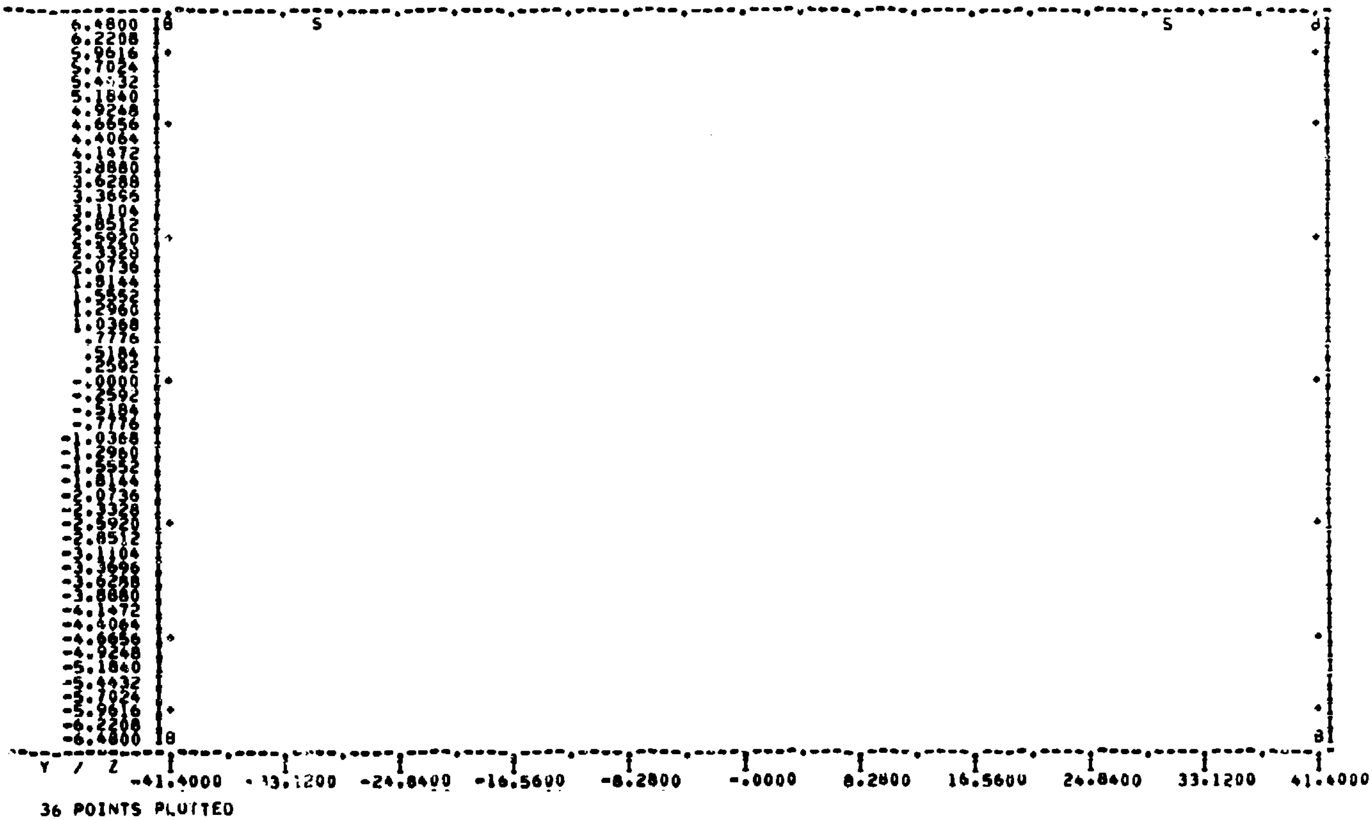


Figure 8c. Continued.

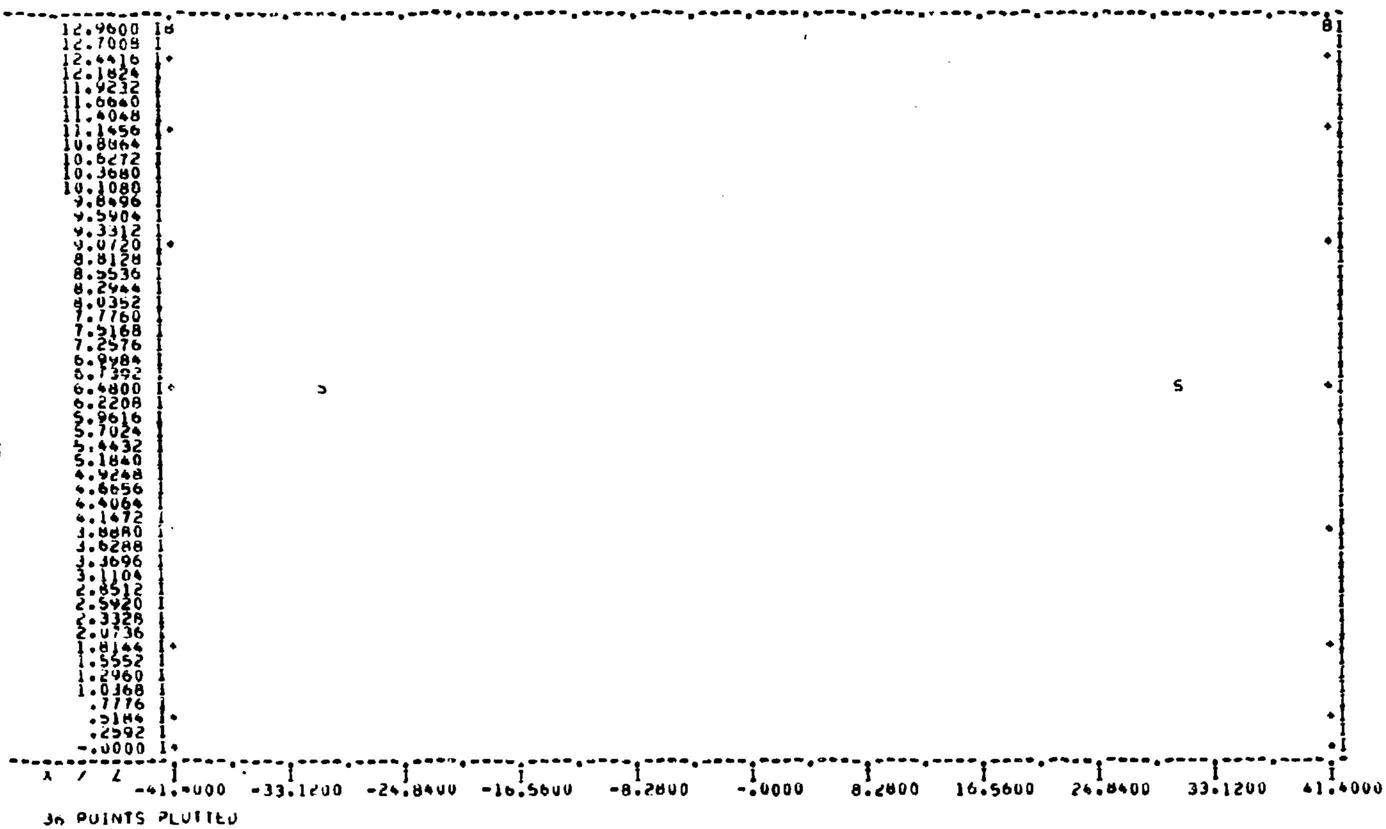


Figure 8c. Concluded.

2.6.2 Problem 2: Wire Antenna on BOT

Consider a right-circular cylinder of 1.0λ length and 0.075λ radius, with a quarter-wave monopole mounted at the cylinder mid-point. The antenna is base-fed.

a) Calculate the power gain patterns in the horizontal ($\phi = 0, 180^{o}$) plane and the roll ($\theta = \pm 90^{o}$) planes in the θ and φ polarization. Use a capped BOT representation for the cylinder, including a junction region, but exclude the edge region between the caps and the BOT.

b) Repeat the foregoing calculations with a parasitic quarter-wave monopole added, mid-point between the active element and the end of the cylinder.

c) Repeat the calculations in a) replacing the monopole with a loop, fed at the midpoint of the cylinder, with an off-set of 0.037λ and a total length of 0.25λ.

Solution - The calculations were carried out with λ = 0.508 m, using four modes (NMODE=4) to represent the BOT currents. The cylinder was represented by NP = 17 points around the circumference. Two end-caps were included (NC = 2) with five points in the radial direction (NPR = 5). Figures 9a-9c list the input data, including wire coordinates, for cases 2a-2c, respectively.

The three problems were solved by first executing the programs BOTZSS, BOTZSC, and BOTZCC using the data file in Figure 9a (see Figures 10-11 and 13-15 for partial outputs). The open BOT system matrix was generated by executing BOTINV with NMODE = 4, NBAND = 14, and zero surface loading (see Figure 12 for a partial output). The closed BOT system matrix was generated by executing BOTINVA with NC = 2, NPR = 5, NE = 0, NW = 0, NPW = 0, NJ = 0, and zero surface loading (see Figure 16 for a partial output). Next, the wire impedance matrices for cases 2a-2c were generated by executing BOTZSW, BOTZCW, and BOTZWW using the data files listed in Figures 9a-9c, respectively (see Figures 17-20, 23-25, and 28-30 for partial output). The system matrix for the closed BOT with wires is obtained by executing BOTINVA for each case. The parameters for case 2a are NC = 0, NPR = 0, NE = 0, NW = 1, NPW = 9, and NJ = 1 (see Figure 21 for a partial output). The parameters for case 2b are NC = 0, NPR = 0, NE = 0, NW = 2, NPW = 18, and NJ = 2 (see Figure 26 for a partial output). The parameters for case 2c are NC = 0, NPR = 0, NE = 0, NW = 1, NPW = 13, NJ = 2 (see Figure 31 for partial output). Once the system matrix for

the closed BOT with wires is obtained, the final results are calculated by executing BOTRA with the appropriate data file from Figures 9a-9c (see Figures 22, 27, and 32 for partial output). In each case, the first junction point is fed. The index of this point in the wire/junction voltage array is (NPW-3*NW)/2+1.

```
 .1229411E+02         BK                                                                    }
 4 20 14              NMODE, NPT, NBAND                                                     }
17                    NP                                                                    }
 .0000   .0146   .0269   .0352   .0381   .0352   .0269   .0146   .0000  -.0146  YB          } BOT data set
-.0269  -.0352  -.0381  -.0352  -.0269  -.0146   .0000                                      }
 .0000   .0029   .0112   .0235   .0381   .0527   .0650   .0733   .0762   .0733  XB          }
 .0650   .0527   .0381   .0235   .0112   .0029   .0000                                      }
 .2540          BL
2  5  0               NC, NPR, NE                }
 .0381   .0000        XC, YC                     }
 .2540  -.2540        ZC                         } Cap data set
 .0000   .2500   .5000   .7500  1.0000   RHOC    }
1  9  1                                                                  NW, NPW, NJ  }
 .0381   .0381   .0381   .0381   .0381   .0381   .0381   .0381   .0381   XW           }
 .0381   .0540   .0698   .0857   .1016   .1175   .1334   .1492   .1651   YW           }
 .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000   ZW           }
      1         INDW                                                                  }
 .0011          RADW                                                                  } Wire data set
      1         INDJW                                                                 }
 .0450          RADD                                                                  }
 .0000          UXJ                                                                   }
1.0000          UYJ                                                                   }
 .0000          UZJ                                                                   }
0      NSA
1                                  }
     4                             } Wire/junction voltage data set
1.0000   .0000                     }
4 37                               }
  90.0     0.0   -90.0    90.0     }
     1       1       1       2     } Radiation angle
   0.0     0.0     0.0   -90.0     }
 180.0   180.0   180.0    90.0     }
0      NTEST
```

Figure 9a. Input data for execution of Problem 2a.

```
 .1229411E+02
 4 20 14
17
  .0000    .0146    .0269    .0352    .0381    .0352    .0269    .0145    .0000   -.0146
 -.0269   -.0352   -.0381   -.0352   -.0269   -.0146    .0000
  .0000    .0029    .0112    .0235    .0381    .0527    .0650    .0733    .0762    .0733
  .0650    .0527    .0381    .0235    .0112    .0029    .0000
  .2540
 2  5   0
  .0381    .0000
  .2540   -.2540
  .0000    .2500    .5000    .7500   1.0000
 2 18   2
  .0381    .0381    .0381    .0381    .0381    .0381    .0381    .0381    .0381    .0381
  .0381    .0381    .0381    .0381    .0381    .0381    .0381    .0381
  .0381    .0540    .0698    .0857    .1016    .1175    .1334    .1492    .1651    .0381
  .0540    .0698    .0857    .1016    .1175    .1334    .1492    .1651
  .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .1270
  .1270    .1270    .1270    .1270    .1270    .1270    .1270    .1270
      1       10
  .0011    .0011
      1       10
  .0450    .0450
  .0000    .0000
 1.0000   1.0000
  .0000    .0000
0      NSA
1
      7
 1.0000    .0000
4 37
  90.0      0.0    -90.0     90.0
     1        1        1        2
   0.0      0.0      0.0    -90.0
 180.0    180.0    180.0     90.0
0      NTEST
```

BOT data set

Cap data set

Wire data set

Wire/junction voltage data set

Radiation angles

Figure 9b. Input data for execution of Problem 2b.

```
 .1229411E+02                                                                                       
 4 20 14
17
  .0000   .0146   .0269   .0352   .0381   .0352   .0269   .0146   .0000  -.0146
 -.0269  -.0352  -.0381  -.0352  -.0269  -.0146   .0000                           BOT data set
  .0000   .0029   .0112   .0235   .0381   .0527   .0650   .0733   .0762   .0733
  .0650   .0527   .0381   .0235   .0112   .0029   .0000
  .2540
 2  5  0
  .0381   .0000                                                                   Cap data set
  .2540  -.2540
  .0000   .2500   .5000   .7500  1.0000
 1 13  2
  .0381   .0381   .0381   .0381   .0381   .0381   .0381   .0381   .0381   .0381
  .0381   .0381   .0381
  .0381   .0475   .0570   .0570   .0570   .0570   .0570   .0570   .0570   .0570
  .0570   .0475   .0381
  .0000   .0000   .0000   .0159   .0318   .0476   .0635   .0794   .0953   .1111
  .1270   .1270   .1270                                                           Wire data set
      1
  .001
      1      13
  .0450   .0450
  .0000   .0000
 1.0000  1.0000
  .0000   .0000
 0      NSA
 1
      6                       Wire/junction voltage data set
 1.0000   .0000
 4 37
   90.0     0.0   -90.0    90.0
      1       1       1       2
    0.0     0.0     0.0   -90.0     Radiation angles
  180.0   180.0   180.0    90.0
 0      NTEST
```

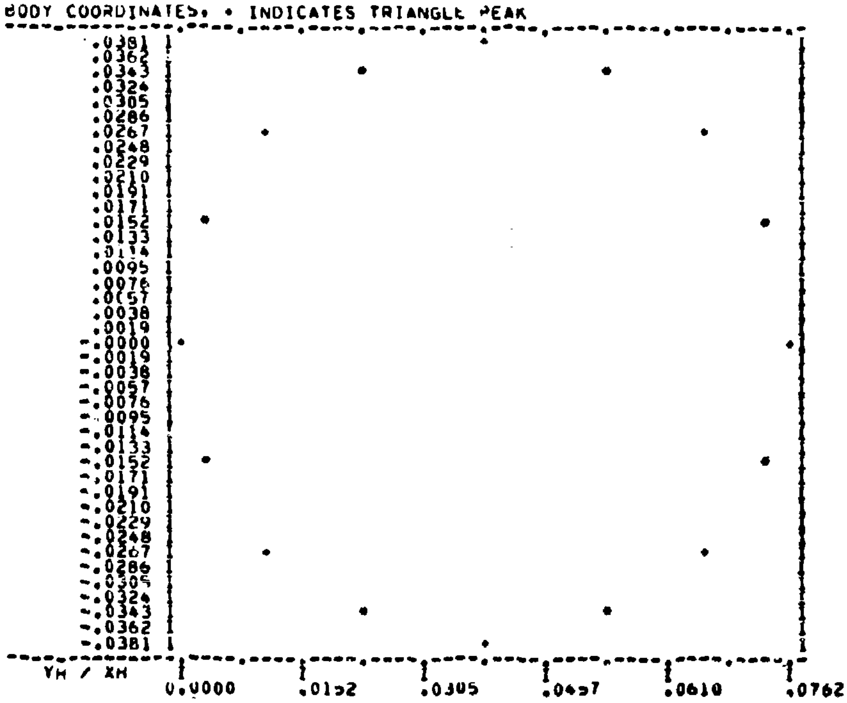
Figure 9c. Input data for execution of Problem 2c.

```
     BK
 .1229411E+02
   NMODE      NPT      NBAND      NP
     4         20        14       17

YB
  0.0000   .0146   .0269   .0352   .0381   .0352   .0269   .0145  0.0000  -.0146
  -.0269  -.0352  -.0381  -.0352  -.0269  -.0146  0.0000

XB
  0.0000   .0029   .0112   .0235   .0381   .0527   .0650   .0733   .0762   .0733
   .0650   .0527   .0381   .0235   .0112   .0029  0.0000
```

BODY COORDINATES. * INDICATES TRIANGLE PEAK



HALF-LENGTH OF BOT =   .2540

BOT GENERATING CURVE IS CLOSED. NP = 19

BOT GENERATING CURVE HAS UNIFORM SEGMENTATION

Figure 10. Output of BOT input data for Problems 2a-2c.

```
M=   0   N=   0

NUMBER OF INTEGNATIONS AND AVERAGE NUMBER OF POINTS PER INTEGRATION (SELF AND NON-SELF TERMS, RESPECTIVELY)
       1   65.0              151   17.1

Z S(T) - S(T)
  .1947       -6.653        .1842        2.235        .1521E-01   1.118
 -.1237        .4382        .1521E-01    1.118        .1842       2.235
  .1842       2.235         .1943       -6.649        .1842       2.235
 -.1762        .4284       -.1237        .4382        .1524E-01   1.116
  .1521E-01   1.118         .1842        2.235        .1947      -6.653
 -.1237        .4382       -.1766        .4289       -.1237        .4382
 -.1237        .4382        .1524E-01    1.116        .1842       2.235
  .1524E-01   1.116        -.1237        .4382       -.1762        .4284
 -.1766        .4289       -.1237        .4382        .1521E-01   1.118
  .1842       2.235         .1521E-01    1.118       -.1237        .4382
 -.1237        .4382       -.1762        .4284       -.1237        .4382
  .1943      -6.649         .1842        2.235        .1524E-01   1.116
  .1521E-01   1.118        -.1237        .4382       -.1766        .4289
  .1842       2.235         .1947       -6.653        .1842       2.235
  .1842       2.235         .1524E-01    1.116       -.1237        .4382
  .1524E-01   1.116         .1842        2.235        .1943      -6.649
```

```
-.1237        .4382      -.1766        .4289
 .1524E-01   1.116       -.1237        .4382
 .1842       2.235        .1521E-01   1.118
 .1943      -6.649        .1842       2.235
 .1842       2.235        .1947      -6.653
 .1524E-01   1.116        .1842       2.235
-.1237        .4382       .1521E-01   1.118
-.1762        .4284      -.1237        .4382
```

Figure 11. Partial output of BOTZSS for Problems 2a-2c ($Z^{sttt}_{0,0}$).

```
NP          NMODE          NBAND
19            4             14
```

NMODE and NBAND are user specified

```
T AND Z SURFACE IMPEDANCE LOADING (COMPLEX)

0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000

0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
```

Surface loadings are user specified

```
THE MINIMUM BOTINV ARRAY DIMENSIONS FOR THIS PROBLEM ARE AS FOLLOWS:

     Z          ZI     LOADWGHT      HZ          LH
   12544        256       16          0          112

FULL MATRIX INVERSION


 M= -3   N= -3

Y1
 .1510E-02 -.6456      .3544E-02 -.3856      .1721E-02  .2361     -.1755E-02  .2729E-01 -.2211E-02 -.4315
-.1755E-02  .2729E-01  .1721E-02  .2361      .3544E-02 -.3856
 .3544E-02 -.3856      .1482E-02 -.6474      .3544E-02 -.3856      .1744E-02  .2382     -.1755E-02  .2729E-01
-.2229E-02 -.4338     -.1755E-02  .2729E-01  .1744E-02  .2382
 .1721E-02  .2361      .3544E-02 -.3856      .1510E-02 -.6456      .3544E-02 -.3856      .1721E-02  .2361
-.1755E-02  .2729E-01 -.2211E-02 -.4315     -.1755E-02  .2729E-01
-.1755E-02  .2729E-01  .1744E-02  .2382      .3544E-02 -.3856      .1482E-02 -.6474      .3544E-02 -.3856
 .1744E-02  .2382     -.1755E-02  .2729E-01 -.2229E-02 -.4338
-.2211E-02 -.4315     -.1755E-02  .2729E-01  .1721E-02  .2361      .3544E-02 -.3856      .1510E-02 -.6456
 .3544E-02 -.3856      .1721E-02  .2361     -.1755E-02  .2729E-01
-.1755E-02  .2729E-01 -.2229E-02 -.4338     -.1755E-02  .2729E-01  .1744E-02  .2382      .3544E-02 -.3856
 .1482E-02 -.6474      .3544E-02 -.3856      .1744E-02  .2382
 .1721E-02  .2361     -.1755E-02  .2729E-01 -.2211E-02 -.4315     -.1755E-02  .2729E-01  .1721E-02  .2361
 .3544E-02 -.3856      .1510E-02 -.6456      .3544E-02 -.3856
 .3544E-02 -.3856      .1744E-02  .2382     -.1755E-02  .2729E-01 -.2229E-02 -.4338     -.1755E-02  .2729E-01
 .1744E-02  .2382      .3544E-02 -.3856      .1482E-02 -.6474
```

Figure 12. Partial output of BOTINV for Problems 2a-2c ($Y^{sstt}_{-3,-3}$).

NC	NPR	NE
2	5	0

CAP	XC	YC	ZC	ZE
1	.0381	0.0000	.2540	
2	.0381	0.0000	-.2540	

RHOC

0.0000	.2500	.5000	.7500	1.0000

Figure 13. Output of cap input data for Problems 2a-2c.

```
M= -3

NUMBER OF INTEGRATIONS AND AVERAGE NUMBER OF POINTS PER INTEGRATION
  2592  43.0

Z S(T) - C(T)
 .4103E-01  .8900E-01 -.4155E-02 -.2475E-01 -.1273E-01 -.1764E-01 -.7011E-02 -.6228E-02 -.5168E-02 -.4309E-02
-.7011E-02 -.6228E-02 -.1273E-01 -.1764E-01 -.4155E-02 -.2475E-01
-.4162E-02 -.2475E-01  .4097E-01  .8893E-01 -.4162E-02 -.2475E-01 -.1270E-01 -.1761E-01 -.7005E-02 -.6224E-02
-.5161E-02 -.4304E-02 -.7005E-02 -.6224E-02 -.1270E-01 -.1761E-01
-.1273E-01 -.1764E-01 -.4155E-02 -.2475E-01  .4103E-01  .8900E-01 -.4155E-02 -.2475E-01 -.1273E-01 -.1764E-01
-.7011E-02 -.6228E-02 -.5168E-02 -.4309E-02 -.7011E-02 -.6228E-02
-.7005E-02 -.6224E-02 -.1270E-01 -.1761E-01 -.4162E-02 -.2475E-01  .4097E-01  .8893E-01 -.4162E-02 -.2475E-01
-.1270E-01 -.1761E-01 -.7005E-02 -.6224E-02 -.5161E-02 -.4304E-02
-.5168E-02 -.4309E-02 -.7011E-02 -.6228E-02 -.1273E-01 -.1764E-01 -.4155E-02 -.2475E-01  .4103E-01  .8900E-01
-.4155E-02 -.2475E-01 -.1273E-01 -.1764E-01 -.7011E-02 -.6228E-02
-.7005E-02 -.6224E-02 -.5161E-02 -.4304E-02 -.7005E-02 -.6224E-02 -.1270E-01 -.1761E-01 -.4162E-02 -.2475E-01
 .4097E-01  .8893E-01 -.4162E-02 -.2475E-01 -.1270E-01 -.1761E-01
-.1273E-01 -.1764E-01 -.7011E-02 -.6228E-02 -.5168E-02 -.4309E-02 -.7011E-02 -.6228E-02 -.1273E-01 -.1764E-01
-.4155E-02 -.2475E-01  .4103E-01  .8900E-01 -.4155E-02 -.2475E-01
-.4162E-02 -.2475E-01 -.1270E-01 -.1761E-01 -.7005E-02 -.6224E-02 -.5161E-02 -.4304E-02 -.7005E-02 -.6224E-02
-.1270E-01 -.1761E-01 -.4162E-02 -.2475E-01  .4097E-01  .8893E-01
-.4095E-01  .8606E-01  .3667E-02 -.2720E-01  .1284E-01 -.1760E-01  .7227E-02 -.4285E-02  .5419E-02 -.1575E-02
 .7227E-02 -.4285E-02  .1284E-01 -.1760E-01  .3667E-02 -.2720E-01
 .3675E-02 -.2721E-01 -.4090E-01  .8599E-01  .3675E-02 -.2721E-01  .1282E-01 -.1757E-01  .7221E-02 -.4280E-02
 .5411E-02 -.1574E-02  .7221E-02 -.4280E-02  .1282E-01 -.1757E-01
 .1284E-01 -.1760E-01  .3667E-02 -.2720E-01 -.4095E-01  .8606E-01  .3667E-02 -.2720E-01  .1284E-01 -.1760E-01
 .7227E-02 -.4285E-02  .5419E-02 -.1575E-02  .7227E-02 -.4285E-02
 .7221E-02 -.4280E-02  .1282E-01 -.1757E-01  .3675E-02 -.2721E-01 -.4090E-01  .8599E-01  .3675E-02 -.2721E-01
 .1282E-01 -.1757E-01  .7221E-02 -.4280E-02  .5411E-02 -.1574E-02
 .5419E-02 -.1575E-02  .7227E-02 -.4285E-02  .1284E-01 -.1760E-01  .3667E-02 -.2720E-01 -.4095E-01  .8606E-01
 .3667E-02 -.2720E-01  .1284E-01 -.1760E-01  .7227E-02 -.4285E-02
 .7221E-02 -.4280E-02  .5411E-02 -.1574E-02  .7221E-02 -.4280E-02  .1282E-01 -.1757E-01  .3675E-02 -.2721E-01
-.4090E-01  .8599E-01  .3675E-02 -.2721E-01  .1282E-01 -.1757E-01
 .1284E-01 -.1760E-01  .7227E-02 -.4285E-02  .5419E-02 -.1575E-02  .7227E-02 -.4285E-02  .1284E-01 -.1760E-01
 .3667E-02 -.2720E-01 -.4095E-01  .8606E-01  .3667E-02 -.2720E-01
 .3675E-02 -.2721E-01  .1282E-01 -.1757E-01  .7221E-02 -.4280E-02  .5411E-02 -.1574E-02  .7221E-02 -.4280E-02
 .1282E-01 -.1757E-01  .3675E-02 -.2721E-01 -.4090E-01  .8599E-01
```

$Z^{sc,tt}_{-3}$

```
Z S(2) - C(T)
 .2265E-14 -.7766E-14  .4384E-01 -.3024E-01  .1522E-01 -.2025E-01  .3984E-02 -.8785E-02 -.1568E-14 -.3232E-14
-.3984E-02  .8785E-02 -.1522E-01  .2025E-01 -.4384E-01  .3024E-01
-.4379E-01  .3019E-01  .2388E-14 -.7405E-14  .4379E-01 -.3019E-01  .1519E-01 -.2022E-01  .3984E-02 -.8776E-02
-.1772E-14 -.2643E-14 -.3984E-02  .8776E-02 -.1519E-01  .2022E-01
-.1522E-01  .2025E-01 -.4384E-01  .3024E-01  .6052E-14 -.9445E-14  .4384E-01 -.3024E-01  .1522E-01 -.2025E-01
 .3984E-02 -.8785E-02 -.1980E-14 -.3583E-14 -.3984E-02  .8785E-02
-.3904E-02  .8776E-02 -.1519E-01  .2022E-01 -.4379E-01  .3019E-01  .2912E-14 -.8167E-14  .4379E-01 -.3019E-01
 .1519E-01 -.2022E-01  .3984E-02 -.8776E-02 -.2049E-14 -.3109E-14
-.1575E-14 -.2693E-14 -.3984E-02  .8785E-02 -.1522E-01  .2025E-01 -.4384E-01  .3024E-01  .1941E-14 -.5224E-14
 .4384E-01 -.3024E-01  .1522E-01 -.2025E-01  .3984E-02 -.8785E-02
 .3984E-02 -.8776E-02 -.2315E-14 -.3340E-14 -.3984E-02  .8776E-02 -.1519E-01  .2022E-01 -.4379E-01  .3019E-01
 .2804E-14 -.8120E-14  .4379E-01 -.3019E-01  .1519E-01 -.2022E-01
 .1522E-01 -.2025E-01  .3984E-02 -.8784E-02 -.1710E-14 -.3247E-14 -.3984E-02  .8785E-02 -.1522E-01  .2025E-01
-.4384E-01  .3024E-01  .3267E-14 -.6249E-14  .4384E-01 -.3024E-01
 .4379E-01 -.3019E-01  .1519E-01 -.2022E-01  .3984E-02 -.8776E-02 -.1953E-14 -.2762E-14 -.3984E-02  .8776E-02
-.1519E-01  .2022E-01 -.4379E-01  .3019E-01  .2743E-14 -.7504E-14
 .8043E-14  .6410E-14  .4548E-01  .3019E-01  .1745E-01  .2035E-01  .5604E-02  .8778E-02  .3671E-14  .2219E-14
-.5604E-02 -.8778E-02 -.1745E-01 -.2035E-01 -.4548E-01 -.3019E-01
-.4543E-01 -.3015E-01  .7828E-14  .8120E-14  .4563E-01  .3015E-01  .1742E-01  .2032E-01  .5600E-02  .8769E-02
 .3463E-14  .2361E-14 -.5600E-02 -.8769E-02 -.1742E-01 -.2032E-01
 .1745E-01  .2035E-01  .4548E-01  .3019E-01  .9461E-14  .9862E-14  .4548E-01  .3019E-01  .1745E-01  .2035E-01
 .5604E-02  .8778E-02  .3760E-14  .2758E-14 -.5604E-02 -.8778E-02
-.5600E-02 -.8769E-02 -.1742E-01 -.2032E-01 -.4543E-01 -.3015E-01  .8063E-14  .7356E-14  .4543E-01  .3015E-01
 .1742E-01  .2032E-01  .5600E-02  .8769E-02  .3979E-14  .2423E-14
 .3671E-14  .1926E-14 -.5604E-02 -.8778E-02 -.1745E-01 -.2035E-01 -.4548E-01 -.3019E-01  .7612E-14  .5100E-14
 .4548E-01  .3019E-01  .1745E-01  .2035E-01  .5604E-02  .8778E-02
 .5600E-02  .8769E-02  .3968E-14  .2488E-14 -.5600E-02 -.8769E-02 -.1742E-01 -.2032E-01 -.4543E-01 -.3015E-01
 .8937E-15  .8321E-14  .4543E-01  .3015E-01  .1742E-01  .2032E-01
 .1745E-01  .2035E-01  .5504E-02  .8778E-02  .3301E-14  .2361E-14 -.5604E-02 -.8778E-02 -.1745E-01 -.2035E-01
-.4548E-01 -.3019E-01  .6660E-14  .6595E-14  .4548E-01  .3019E-01
 .4543E-01  .3015E-01  .1742E-01  .2032E-01  .5600E-02  .8769E-02  .3817E-14  .2465E-14 -.5600E-02 -.8769E-02
-.1742E-01 -.2032E-01 -.4543E-01 -.3013E-01  .7735E-14  .7858E-14
```

$Z^{sc,zt}_{-3}$

Figure 14. Partial output of BOTZSC for Problems 2a-2c.

Z S(T) - C(R)

.1412E-15	.4550E-15	-.8269E-02	-.1709E-01	-.2764E-02	-.3096E-02
.3929E-03	.2945E-03	.2764E-02	.3096E-02	.8269E-02	.1709E-01
.8279E-02	.1711E-01	.9415E-16	.6590E-15	-.8279E-02	-.1711E-01
.3531E-16	-.2746E-16	.3920E-03	.2943E-03	.2760E-02	.3090E-02
.2764E-02	.3096E-02	.8269E-02	.1709E-01	.3295E-15	.8787E-15
-.3928E-03	-.2945E-03	.7257E-16	-.1765E-16	.3928E-03	.2945E-03
.3920E-03	.2943E-03	.2760E-02	.3090E-02	.8279E-02	.1711E-01
-.2760E-02	-.3090E-02	-.3920E-03	-.2943E-03	-.6665E-16	-.9807E-17
-.1098E-15	-.1961E-16	.3928E-03	.2945E-03	.2764E-02	.3096E-02
-.8269E-02	-.1709E-01	-.2764E-02	-.3096E-02	-.3928E-03	-.2945E-03
-.3920E-03	-.2943E-03	-.6277E-16	0.	.3920E-03	.2943E-03
.2981E-15	.8473E-15	-.8279E-02	-.1711E-01	-.2760E-02	-.3090E-02
-.2764E-02	-.3096E-02	-.3928E-03	-.2945E-03	-.5884E-17	.3334E-16
.8269E-02	.1709E-01	.4394E-15	.1344E-14	-.8269E-02	-.1709E-01
-.8279E-02	-.1711E-01	-.2760E-02	-.3090E-02	-.3920E-03	-.2943E-03
.2760E-02	.3090E-02	.8279E-02	.1711E-01	.1883E-15	.6433E-15
.1569E-16	.6277E-16	.8290E-02	-.1631E-01	.2855E-02	-.1960E-02
-.4511E-03	-.4659E-03	-.2855E-02	.1960E-02	-.8290E-02	.1631E-01
-.8301E-02	.1633E-01	-.1726E-15	.5178E-15	.8301E-02	-.1633E-01
-.9807E-17	.3138E-16	-.4504E-03	-.4873E-03	-.2851E-02	.1955E-02
-.2855E-02	.1960E-02	-.8290E-02	.1631E-01	-.3138E-15	.7846E-15
.4511E-03	.4859E-03	.3727E-16	.3923E-17	-.4511E-03	-.4859E-03
-.4504E-03	-.4873E-03	-.2851E-02	.1955E-02	-.8301E-02	.1633E-01
.2851E-02	-.1955E-02	.4504E-03	.4873E-03	.3531E-16	.7846E-17
.3138E-16	-.5884E-16	-.4511E-03	-.4859E-03	-.2855E-02	.1960E-02
.8290E-02	-.1631E-01	.2855E-02	-.1960E-02	.4511E-03	.4859E-03
.4504E-03	.4873E-03	.7650E-16	-.4315E-16	-.4504E-03	-.4873E-03
-.2197E-15	.5963E-15	.8301E-02	-.1633E-01	.2851E-02	-.1955E-02
.2855E-02	-.1960E-02	.4511E-03	.4859E-03	.2550E-16	-.3531E-16
-.8290E-02	.1631E-01	-.4550E-15	.1381E-14	.8290E-02	-.1631E-01
.8301E-02	-.1633E-01	.2851E-02	-.1955E-02	.4504E-03	.4873E-03
-.2851E-02	.1955E-02	-.8301E-02	.1633E-01	-.2060E-15	.6904E-15

$Z^{sc,t\rho}_{-3}$

-.3928E-03	-.2945E-03	0.	-.8236E-16
-.2760E-02	-.3090E-02	-.3920E-03	-.2943E-03
-.8269E-02	-.1709E-01	-.2764E-02	-.3096E-02
.2511E-15	.6904E-15	-.8279E-02	-.1711E-01
.8269E-02	.1709E-01	.1883E-15	.7218E-15
.2760E-02	.3090E-02	.8279E-02	.1711E-01
.3928E-03	.2945E-03	.2764E-02	.3096E-02
-.2942E-16	-.1765E-16	.3920E-03	.2943E-03
.4511E-03	.4859E-03	.2746E-16	-.2354E-15
.2851E-02	-.1955E-02	.4504E-03	.4873E-03
.8290E-02	-.1631E-01	.2855E-02	-.1960E-02
-.1569E-15	.7375E-15	.8301E-02	-.1633E-01
-.8290E-02	.1631E-01	-.7846E-16	.4707E-15
-.2851E-02	.1955E-02	-.8301E-02	.1633E-01
-.4511E-03	-.4859E-03	-.2855E-02	.1960E-02
.3727E-16	-.1177E-16	-.4504E-03	-.4873E-03

Z S(Z) - C(R)

.2226E-01	-.1094E-01	.8414E-02	-.4037E-02	-.1935E-02	.3756E-02
-.3045E-02	.6583E-02	-.1935E-02	.3756E-02	.8414E-02	-.4037E-02
.8411E-02	-.4032E-02	.2228E-01	-.1095E-01	.8411E-02	-.4032E-02
-.2972E-02	.7220E-02	-.3048E-02	.6586E-02	-.1937E-02	.3758E-02
-.1935E-02	.3756E-02	.8414E-02	-.4037E-02	.2226E-01	-.1094E-01
-.3045E-02	.6583E-02	-.2974E-02	.7220E-02	-.3045E-02	.6583E-02
-.3048E-02	.6586E-02	-.1937E-02	.3758E-02	.8411E-02	-.4032E-02
-.1937E-02	.3758E-02	-.3048E-02	.6586E-02	-.2972E-02	.7220E-02
-.2974E-02	.7220E-02	-.3045E-02	.6583E-02	-.1935E-02	.3756E-02
.8414E-02	-.4037E-02	-.1935E-02	.3756E-02	-.3045E-02	.6583E-02
-.3048E-02	.6586E-02	-.2972E-02	.7220E-02	-.3048E-02	.6586E-02
.2228E-01	-.1095E-01	.8411E-02	-.4032E-02	-.1937E-02	.3758E-02
-.1935E-02	.3756E-02	-.3045E-02	.6583E-02	-.2974E-02	.7220E-02
.8414E-02	-.4037E-02	.2226E-01	-.1094E-01	.8414E-02	-.4037E-02
.8411E-02	-.4032E-02	-.1937E-02	.3758E-02	-.3048E-02	.6586E-02
-.1937E-02	.3758E-02	.8411E-02	-.4032E-02	.2228E-01	-.1095E-01
.2264E-01	.1087E-01	.8504E-02	.4003E-02	-.2491E-02	-.3760E-02
-.4218E-02	-.6572E-02	-.2491E-02	-.3760E-02	.8504E-02	.4003E-02
.8501E-02	.3998E-02	.2267E-01	.1088E-01	.8501E-02	.3998E-02
-.4398E-02	-.7201E-02	-.4221E-02	-.6575E-02	-.2493E-02	-.3762E-02
-.2491E-02	-.3760E-02	.8504E-02	.4003E-02	.2264E-01	.1087E-01
-.4218E-02	-.6572E-02	-.4400E-02	-.7201E-02	-.4218E-02	-.6572E-02
-.4221E-02	-.6575E-02	-.2493E-02	-.3762E-02	.8501E-02	.3998E-02
-.2493E-02	-.3762E-02	-.4221E-02	-.6575E-02	-.4398E-02	-.7201E-02
-.4400E-02	-.7201E-02	-.4218E-02	-.6572E-02	-.2491E-02	-.3760E-02
.8504E-02	.4003E-02	-.2491E-02	-.3760E-02	-.4218E-02	-.6572E-02
-.4221E-02	-.6575E-02	-.4398E-02	-.7201E-02	-.4221E-02	-.6575E-02
.2267E-01	.1088E-01	.8501E-02	.3998E-02	-.2493E-02	-.3762E-02
-.2491E-02	-.3760E-02	-.4218E-02	-.6572E-02	-.4400E-02	-.7201E-02
.8504E-02	.4003E-02	.2264E-01	.1087E-01	.8504E-02	.4003E-02
.8501E-02	.3998E-02	-.2493E-02	-.3762E-02	-.4221E-02	-.6575E-02
-.2493E-02	-.3762E-02	.8501E-02	.3998E-02	.2267E-01	.1088E-01

$Z^{sc,z\rho}_{-3}$

-.3045E-02	.6583E-02	-.2974E-02	.7220E-02
-.1937E-02	.3758E-02	-.3048E-02	.6586E-02
.8414E-02	-.4037E-02	-.1935E-02	.3756E-02
.2228E-01	-.1095E-01	.8411E-02	-.4032E-02
.8414E-02	-.4037E-02	.2226E-01	-.1094E-01
-.1937E-02	.3758E-02	.8411E-02	-.4032E-02
-.3045E-02	.6583E-02	-.1935E-02	.3756E-02
-.2972E-02	.7220E-02	-.3048E-02	.6586E-02
-.4218E-02	-.6572E-02	-.4400E-02	-.7201E-02
-.2493E-02	-.3762E-02	-.4221E-02	-.6575E-02
.8504E-02	.4003E-02	-.2491E-02	-.3760E-02
.2267E-01	.1088E-01	.8501E-02	.3998E-02
.8504E-02	.4003E-02	.2264E-01	.1087E-01
-.2493E-02	-.3762E-02	.8501E-02	.3998E-02
-.4218E-02	-.6572E-02	-.2491E-02	-.3760E-02
-.4398E-02	-.7201E-02	-.4221E-02	-.6575E-02

Figure 14. Concluded.

```
NUMBER OF INTEGRATIONS AND AVERAGE NUMBER OF POINTS PER INTEGRATION FOR SELF TERM
      72   7.00

Z C(T) - C(T)
  .1777E-02 -.2810       .8215E-03  .7659E-01  .2911E-04  .5536E-01 -.9166E-03  .1606E-01 -.1300E-02  .1033E-01
 -.9166E-03  .1606E-01   .2911E-04  .5536E-01  .8215E-03  .7659E-01  .4313E-04  .3358E-03  .3073E-04  .2367E-03
 -.1681E-05 -.5166E-06  -.3778E-04 -.2357E-03 -.5387E-04 -.3327E-03 -.3778E-04 -.2357E-03 -.1681E-05 -.5166E-06
  .3073E-04  .2367E-03
  .8215E-03  .7659E-01   .1776E-02 -.2808      .8215E-03  .7659E-01  .2918E-04  .5526E-01 -.9166E-03  .1606E-01
 -.1299E-02  .1031E-01  -.9166E-03  .1606E-01  .2918E-04  .5526E-01  .3073E-04  .2367E-03  .4299E-04  .3353E-03
  .3073E-04  .2367E-03  -.1689E-05 -.5133E-06 -.3778E-04 -.2357E-03 -.5374E-04 -.3323E-03 -.3778E-04 -.2357E-03
 -.1689E-05 -.5133E-06
  .2911E-04  .5536E-01   .8215E-03  .7659E-01  .1777E-02 -.2810      .8215E-03  .7659E-01  .2911E-04  .5536E-01
 -.9166E-03  .1606E-01  -.1300E-02  .1033E-01 -.9166E-03  .1606E-01 -.1681E-05 -.5166E-06  .3073E-04  .2367E-03
  .4313E-04  .3358E-03   .3073E-04  .2367E-03 -.1681E-05 -.5166E-06 -.3778E-04 -.2357E-03 -.5387E-04 -.3327E-03
 -.3778E-04 -.2357E-03
 -.9166E-03  .1606E-01   .2918E-04  .5526E-01  .8215E-03  .7659E-01  .1776E-02 -.2808      .8215E-03  .7659E-01
  .2918E-04  .5526E-01  -.9166E-03  .1606E-01 -.1299E-02  .1031E-01 -.3778E-04 -.2357E-03 -.1689E-05 -.5133E-06
  .3073E-04  .2367E-03   .4299E-04  .3353E-03  .3073E-04  .2367E-03 -.1689E-05 -.5133E-06 -.3778E-04 -.2357E-03
 -.5374E-04 -.3323E-03
 -.1300E-02  .1033E-01  -.9166E-03  .1606E-01  .2911E-04  .5536E-01  .8215E-03  .7659E-01  .1777E-02 -.2810
  .8215E-03  .7659E-01   .2911E-04  .5536E-01 -.9166E-03  .1606E-01 -.5387E-04 -.3327E-03 -.3778E-04 -.2357E-03
 -.1681E-05 -.5166E-06   .3073E-04  .2367E-03  .4313E-04  .3358E-03  .3073E-04  .2367E-03 -.1681E-05 -.5166E-05
 -.3778E-04 -.2357E-03
 -.9166E-03  .1606E-01  -.1299E-02  .1031E-01 -.9166E-03  .1606E-01  .2918E-04  .5526E-01  .8215E-03  .7659E-01
  .1776E-02 -.2808       .8215E-03  .7659E-01  .2918E-04  .5526E-01 -.3778E-04 -.2357E-03 -.5374E-04 -.3323E-03
 -.3778E-04 -.2357E-03  -.1689E-05 -.5133E-06  .3073E-04  .2367E-03  .4299E-04  .3353E-03  .3073E-04  .2367E-03
 -.1689E-05 -.5133E-06
  .2911E-04  .5536E-01  -.9166E-03  .1606E-01 -.1300E-02  .1033E-01 -.9166E-03  .1606E-01  .2911E-04  .5536E-01
  .8215E-03  .7659E-01   .1777E-02 -.2810      .8215E-03  .7659E-01 -.1681E-05 -.5166E-06 -.3778E-04 -.2357E-03
 -.5387E-04 -.3327E-03  -.3778E-04 -.2357E-03 -.1681E-05 -.5166E-06  .3073E-04  .2367E-03  .4313E-04  .3358E-03
  .3073E-04  .2367E-03
  .8215E-03  .7659E-01   .2918E-04  .5526E-01 -.9166E-03  .1606E-01 -.1299E-02  .1031E-01 -.9166E-03  .1606E-01
  .2918E-04  .5526E-01   .8215E-03  .7659E-01  .1776E-02 -.2808      .3073E-04  .2367E-03 -.1689E-05 -.5133E-06
 -.3778E-04 -.2357E-03  -.5374E-04 -.3323E-03 -.3778E-04 -.2357E-03 -.1689E-05 -.5133E-06  .3073E-04  .2367E-03
  .4299E-04  .3353E-03
  .4313E-04  .3358E-03   .3073E-04  .2367E-03 -.1681E-05 -.5166E-06 -.3778E-04 -.2357E-03 -.5387E-04 -.3327E-03
 -.3778E-04 -.2357E-03  -.1681E-05 -.5166E-06  .3073E-04  .2367E-03  .1777E-02 -.2810      .8215E-03  .7659E-01
  .2911E-04  .5536E-01  -.9166E-03  .1606E-01 -.1300E-02  .1033E-01 -.9166E-03  .1606E-01  .2911E-04  .5536E-01
  .8215E-03  .7659E-01
  .3073E-04  .2367E-03   .4299E-04  .3353E-03  .3073E-04  .2367E-03 -.1689E-05 -.5133E-06 -.3778E-04 -.2357E-03
 -.5374E-04 -.3323E-03  -.3778E-04 -.2357E-03 -.1689E-05 -.5133E-06  .8215E-03  .7659E-01  .1776E-02 -.2808
  .8215E-03  .7659E-01   .2918E-04  .5526E-01 -.9166E-03  .1606E-01 -.1299E-02  .1031E-01 -.9166E-03  .1606E-01
  .2918E-04  .5526E-01
 -.1681E-05 -.5166E-06   .3073E-04  .2367E-03  .4313E-04  .3358E-03  .3073E-04  .2367E-03 -.1681E-05 -.5166E-05
 -.3778E-04 -.2357E-03  -.5387E-04 -.3327E-03 -.3778E-04 -.2357E-03  .2911E-04  .5536E-01  .8215E-03  .7659E-01
  .1777E-02 -.2810       .8215E-03  .7659E-01  .2911E-04  .5536E-01 -.9166E-03  .1606E-01 -.1300E-02  .1033E-01
 -.9166E-03  .1606E-01
 -.3778E-04 -.2357E-03  -.1689E-05 -.5133E-06  .3073E-04  .2367E-03  .4299E-04  .3353E-03  .3073E-04  .2367E-03
 -.1689E-05 -.5133E-06  -.3778E-04 -.2357E-03 -.5374E-04 -.3323E-03 -.9166E-03  .1606E-01  .2918E-04  .5526E-01
  .8215E-03  .7659E-01   .1776E-02 -.2808      .8215E-03  .7659E-01  .2918E-04  .5526E-01 -.9166E-03  .1606E-01
 -.1299E-02  .1031E-01
 -.5387E-04 -.3327E-03  -.3778E-04 -.2357E-03 -.1681E-05 -.5166E-06  .3073E-04  .2367E-03  .4313E-04  .3358E-03
  .3073E-04  .2367E-03  -.1681E-05 -.5166E-06 -.3778E-04 -.2357E-03 -.1300E-02  .1033E-01 -.9166E-03  .1606E-01
  .2911E-04  .5536E-01   .8215E-03  .7659E-01  .1777E-02 -.2810      .8215E-03  .7659E-01  .2911E-04  .5536E-01
 -.9166E-03  .1606E-01
 -.3778E-04 -.2357E-03  -.5374E-04 -.3323E-03 -.3778E-04 -.2357E-03 -.1689E-05 -.5133E-06  .3073E-04  .2367E-03
  .4299E-04  .3353E-03   .3073E-04  .2367E-03 -.1689E-05 -.5133E-06 -.9166E-03  .1606E-01 -.1299E-02  .1031E-01
 -.9166E-03  .1606E-01   .2918E-04  .5526E-01  .8215E-03  .7659E-01  .1776E-02 -.2808      .8215E-03  .7659E-01
  .2918E-04  .5526E-01
 -.1681E-05 -.5166E-06  -.3778E-04 -.2357E-03 -.5387E-04 -.3327E-03 -.3778E-04 -.2357E-03 -.1681E-05 -.5166E-06
  .3073E-04  .2367E-03   .4313E-04  .3358E-03  .3073E-04  .2367E-03  .2911E-04  .5536E-01 -.9166E-03  .1606E-01
 -.1300E-02  .1033E-01  -.9166E-03  .1606E-01  .2911E-04  .5536E-01  .8215E-03  .7659E-01  .1777E-02 -.2810
  .8215E-03  .7659E-01
  .3073E-04  .2367E-03  -.1689E-05 -.5133E-06 -.3778E-04 -.2357E-03 -.5374E-04 -.3323E-03 -.3778E-04 -.2357E-03
 -.1689E-05 -.5133E-06   .3073E-04  .2367E-03  .4299E-04  .3353E-03  .8215E-03  .7659E-01  .2918E-04  .5526E-01
 -.9166E-03  .1606E-01  -.1299E-02  .1031E-01 -.9166E-03  .1606E-01  .2918E-04  .5526E-01  .8215E-03  .7659E-01
  .1776E-02 -.2808
```

Zcctt

Figure 15. Partial output of BOTZCC for Problems 2a-2c.

Z C(R) - C(T)

.3138E-16	.4613E-14	.4054E-03	-.5608E-02	.5256E-03	.4478E-02	.3667E-03	.2495E-02	.1785E-15	.6212E-14
-.3667E-03	-.2495E-02	-.5256E-03	-.4478E-02	-.4054E-03	.5608E-02	.2299E-19	-.5884E-17	.1214E-04	.9026E-04
.1798E-04	.1272E-03	.1329E-04	.8968E-04	-.1645E-16	.3923E-17	-.1329E-04	-.8968E-04	-.1798E-04	-.1272E-03
-.1214E-04	-.9026E-04								
-.4049E-03	.5624E-02	-.8434E-16	.4080E-14	.4049E-03	-.5624E-02	.5257E-03	.4485E-02	.3664E-03	.2493E-02
.1314E-15	.5453E-14	-.3664E-03	-.2493E-02	-.5257E-03	-.4485E-02	-.1212E-04	-.9016E-04	.1532E-19	-.7846E-17
.1212E-04	.9016E-04	.1796E-04	.1272E-03	.1327E-04	.8958E-04	-.1583E-16	0.	-.1327E-04	-.8958E-04
-.1796E-04	-.1272E-03								
-.5256E-03	-.4478E-02	-.4054E-03	.5608E-02	-.6669E-16	.5790E-14	.4054E-03	-.5608E-02	.5256E-03	.4478E-02
.3667E-03	.2495E-02	.2864E-15	.6451E-14	-.3667E-03	-.2495E-02	-.1798E-04	-.1272E-03	-.1214E-04	-.9026E-04
-.1532E-18	.1716E-17	.1214E-04	.9026E-04	.1798E-04	.1272E-03	.1329E-04	.8968E-04	-.1686E-16	.1103E-15
-.1329E-04	-.8968E-04								
-.3664E-03	-.2493E-02	-.5257E-03	-.4485E-02	-.4049E-03	.5624E-02	-.1961E-17	.4315E-14	.4049E-03	-.5624E-02
.5257E-03	.4485E-02	.3664E-03	.2493E-02	.2001E-15	.5753E-14	-.1327E-04	-.8958E-04	-.1796E-04	-.1272E-03
-.1212E-04	-.9016E-04	-.2758E-18	-.1716E-17	.1212E-04	.9016E-04	.1796E-04	.1272E-03	.1327E-04	.8958E-04
-.1679E-16	.6865E-17								
.8238E-16	.5472E-14	-.3667E-03	-.2495E-02	-.5256E-03	-.4478E-02	-.4054E-03	.5608E-02	.2746E-16	.3264E-14
.4054E-03	-.5608E-02	.5256E-03	.4478E-02	.3667E-03	.2495E-02	-.1545E-16	-.1226E-17	-.1329E-04	-.8968E-04
-.1798E-04	-.1272E-03	-.1214E-04	-.9026E-04	-.2452E-18	-.6865E-17	.1214E-04	.9026E-04	.1798E-04	.1272E-03
.1329E-04	.8968E-04								
.3664E-03	.2493E-02	.2432E-15	.5692E-14	-.3664E-03	-.2493E-02	-.5257E-03	-.4485E-02	-.4049E-03	.5624E-02
.4119E-16	.4613E-14	.4049E-03	-.5624E-02	.5257E-03	.4485E-02	.1327E-04	.8958E-04	-.1799E-16	.1177E-16
-.1327E-04	-.8958E-04	-.1796E-04	-.1272E-03	-.1212E-04	-.9016E-04	-.3984E-18	-.1226E-17	.1212E-04	.9016E-04
.1796E-04	.1272E-03								
.5256E-03	.4478E-02	.3667E-03	.2495E-02	.2118E-15	.5745E-14	-.3667E-03	-.2495E-02	-.5256E-03	-.4478E-02
-.4054E-03	.5608E-02	-.6277E-16	.4284E-14	.4054E-03	-.5608E-02	.1798E-04	.1272E-03	.1329E-04	.8968E-04
-.1558E-16	.6375E-17	-.1329E-04	-.8968E-04	-.1798E-04	-.1272E-03	-.1214E-04	-.9026E-04	-.3984E-18	-.3678E-17
.1214E-04	.9026E-04								
.4049E-03	-.5624E-02	.5257E-03	.4485E-02	.3664E-03	.2493E-02	.2118E-15	.5669E-14	-.3664E-03	-.2493E-02
-.5257E-03	-.4485E-02	-.4049E-03	.5624E-02	-.5884E-17	.4864E-14	.1212E-04	.9016E-04	-.1796E-04	-.1272E-03
.1327E-04	.8958E-04	-.1663E-16	.6375E-17	-.1327E-04	-.8958E-04	-.1796E-04	-.1272E-03	-.1212E-04	-.9016E-04
-.2222E-18	-.5149E-17								
.2299E-19	-.5884E-17	.1214E-04	.9026E-04	.1798E-04	.1272E-03	.1329E-04	.8968E-04	-.1645E-16	.3923E-17
-.1329E-04	-.8968E-04	-.1798E-04	-.1272E-03	-.1214E-04	-.9026E-04	.4138E-16	.4613E-14	.4054E-03	-.5608E-02
.5256E-03	.4478E-02	.3667E-03	.2495E-02	.1785E-15	.6212E-14	-.3667E-03	-.2495E-02	-.5256E-03	-.4478E-02
-.4054E-03	.5608E-02								
-.1212E-04	-.9016E-04	.1532E-19	-.7846E-17	.1212E-04	.9016E-04	.1796E-04	.1272E-03	.1327E-04	.8958E-04
-.1583E-16	0.	-.1327E-04	-.8958E-04	-.1796E-04	-.1272E-03	-.4049E-03	.5624E-02	-.8434E-16	.4080E-14
.4049E-03	-.5624E-02	.5257E-03	.4485E-02	.3664E-03	.2493E-02	.1314E-15	.5453E-14	-.3664E-03	-.2493E-02
-.5257E-03	-.4485E-02								
-.1798E-04	-.1272E-03	-.1214E-04	-.9026E-04	-.1532E-18	.1716E-17	.1214E-04	.9026E-04	.1798E-04	.1272E-03
.1329E-04	.8968E-04	-.1686E-16	.1103E-16	-.1329E-04	-.8968E-04	-.5256E-03	-.4478E-02	-.4054E-03	.5608E-02
-.6669E-16	.5790E-14	.4054E-03	-.5608E-02	.5256E-03	.4478E-02	.3667E-03	.2495E-02	.2864E-15	.6451E-14
-.3667E-03	-.2495E-02								
-.1327E-04	-.8958E-04	-.1796E-04	-.1272E-03	-.1212E-04	-.9016E-04	-.2758E-18	-.1716E-17	.1212E-04	.9016E-04
.1796E-04	.1272E-03	.1327E-04	.8958E-04	-.1679E-16	.6865E-17	-.3664E-03	-.2493E-02	-.5257E-03	-.4485E-02
-.4049E-03	.5624E-02	-.1961E-17	.4315E-14	.4049E-03	-.5624E-02	.5257E-03	.4485E-02	.3664E-03	.2493E-02
.2001E-15	.5753E-14								
-.1545E-16	-.1226E-17	-.1329E-04	-.8968E-04	-.1798E-04	-.1272E-03	-.1214E-04	-.9026E-04	-.2452E-18	-.6865E-17
.1214E-04	.9026E-04	.1798E-04	.1272E-03	.1329E-04	.8968E-04	.8238E-16	.5472E-14	-.3667E-03	-.2495E-02
-.5256E-03	-.4478E-02	-.4054E-03	.5608E-02	.2746E-16	.3264E-14	.4054E-03	-.5608E-02	.5256E-03	.4478E-02
.3667E-03	.2495E-02								
.1327E-04	.8958E-04	-.1799E-16	.1177E-16	-.1327E-04	-.8958E-04	-.1796E-04	-.1272E-03	-.1212E-04	-.9016E-04
-.3984E-18	-.1226E-17	.1212E-04	.9016E-04	.1796E-04	.1272E-03	.3664E-03	.2493E-02	.2432E-15	.5692E-14
-.3664E-03	-.2493E-02	-.5257E-03	-.4485E-02	-.4049E-03	.5624E-02	.4119E-16	.4613E-14	.4049E-03	-.5624E-02
.5257E-03	.4485E-02								
.1798E-04	.1272E-03	.1329E-04	.8968E-04	-.1558E-16	.6375E-17	-.1329E-04	-.8968E-04	-.1798E-04	-.1272E-03
-.1214E-04	-.9026E-04	-.3984E-18	-.3678E-17	.1214E-04	.9026E-04	.5256E-03	.4478E-02	.3667E-03	.2495E-02
.2118E-15	.5745E-14	-.3667E-03	-.2495E-02	-.5256E-03	-.4478E-02	-.4054E-03	.5608E-02	-.6277E-16	.4284E-14
.4054E-03	-.5608E-02								
.1212E-04	.9016E-04	.1796E-04	.1272E-03	.1327E-04	.8958E-04	-.1663E-16	.6375E-17	-.1327E-04	-.8958E-04
-.1796E-04	-.1272E-03	-.1212E-04	-.9015E-04	-.2222E-18	-.5149E-17	.4049E-03	-.5624E-02	.5257E-03	.4485E-02
.3664E-03	.2493E-02	.2118E-15	.5669E-14	-.3664E-03	-.2493E-02	-.5257E-03	-.4485E-02	-.4049E-03	.5624E-02
-.5884E-17	.4864E-14								

Figure 15. Continued.

```
Z C(T) - C(H)
 .1157E-15 -.1193E-14 -.4049E-03  .5624E-02 -.5256E-03 -.4478E-02 -.3664E-03 -.2493E-02 -.9807E-17 -.1961E-17
 .3664E-03  .2493E-02  .5256E-03  .4478E-02  .4049E-03 -.5624E-02  .5670E-18  .1373E-16 -.1212E-04 -.9016E-04
-.1798E-04 -.1272E-03 -.1327E-04 -.8958E-04 -.1356E-17  .1299E-16  .1327E-04  .8958E-04  .1798E-04  .1272E-03
 .1212E-04  .9016E-04
 .4054E-03 -.5608E-02  .1961E-16 -.2087E-14 -.4054E-03  .5608E-02 -.5257E-03 -.4485E-02 -.3667E-03 -.2495E-02
 .7257E-16  .2471E-15  .3667E-03  .2495E-02  .5257E-03  .4485E-02  .1214E-04  .9026E-04  .5593E-18  .7110E-17
-.1214E-04 -.9026E-04 -.1796E-04 -.1272E-03 -.1329E-04 -.8968E-04 -.1639E-17 -.3923E-17  .1329E-04  .8968E-04
 .1796E-04  .1272E-03
 .5256E-03  .4478E-02  .4049E-03 -.5624E-02 -.3138E-16 -.1726E-15 -.4049E-03  .5624E-02 -.5256E-03 -.4478E-02
-.3664E-03 -.2493E-02 0.          .1098E-15  .3664E-03  .2493E-02  .1798E-04  .1272E-03  .1212E-04  .9016E-04
 .6436E-18 -.1471E-17 -.1212E-04 -.9016E-04 -.1798E-04 -.1272E-03 -.1327E-04 -.8958E-04 -.1540E-17 -.6375E-17
 .1327E-04  .8958E-04
 .3667E-03  .2495E-02  .5257E-03  .4485E-02  .4054E-03 -.5608E-02  .7846E-17 -.1899E-14 -.4054E-03  .5608E-02
-.5257E-03 -.4485E-02 -.3667E-03 -.2495E-02  .2158E-16  .1196E-15  .1329E-04  .8968E-04  .1796E-04  .1272E-03
 .1214E-04  .9026E-04  .7049E-18 -.2452E-17 -.1214E-04 -.9026E-04 -.1796E-04 -.1272E-03 -.1329E-04 -.8968E-04
-.1582E-17 -.4658E-17
 .3138E-16  .2864E-15  .3664E-03  .2493E-02  .5256E-03  .4478E-02  .4049E-03 -.5624E-02  .1079E-15 -.2872E-14
-.4049E-03  .5624E-02 -.5256E-03 -.4478E-02 -.3664E-03 -.2493E-02 -.1900E-17  .7601E-17  .1327E-04  .8958E-04
 .1798E-04  .1272E-03  .1212E-04  .9016E-04  .4291E-18  .9072E-17 -.1212E-04 -.9016E-04 -.1798E-04 -.1272E-03
-.1327E-04 -.8958E-04
-.3667E-03 -.2495E-02  .7453E-16  .3138E-16  .3667E-03  .2495E-02  .5257E-03  .4485E-02  .4054E-03 -.5608E-02
 .7846E-16 -.1161E-14 -.4054E-03  .5608E-02 -.5257E-03 -.4485E-02 -.1329E-04 -.8968E-04 -.1437E-17 -.8581E-17
 .1329E-04  .8968E-04  .1796E-04  .1272E-03  .1214E-04  .9026E-04  .4904E-18  .5149E-17 -.1214E-04 -.9026E-04
-.1796E-04 -.1272E-03
-.5256E-03 -.4478E-02 -.3664E-03 -.2493E-02  .1020E-15  .3276E-15  .3664E-03  .2493E-02  .5256E-03  .4478E-02
 .4049E-03 -.5624E-02 -.3923E-17 -.2448E-14 -.4049E-03  .5624E-02 -.1798E-04 -.1272E-03 -.1327E-04 -.8958E-04
-.1935E-17 -.1250E-16  .1327E-04  .8958E-04  .1798E-04  .1272E-03  .1212E-04  .9016E-04  .9730E-18  .1618E-15
-.1212E-04 -.9016E-04
-.4054E-03  .5608E-02 -.5257E-03 -.4485E-02 -.3667E-03 -.2495E-02  .4511E-16  .2118E-15  .3667E-03  .2495E-02
 .5257E-03  .4485E-02  .4054E-03 -.5608E-02  .2354E-16 -.1051E-14 -.1214E-04 -.9026E-04 -.1796E-04 -.1272E-03
-.1329E-04 -.8968E-04 -.1536E-17 -.4904E-18  .1329E-04  .8968E-04  .1796E-04  .1272E-03  .1214E-04  .9026E-04
 .6129E-18  .6129E-17
 .5670E-18  .1373E-16 -.1212E-04 -.9015E-04 -.1798E-04 -.1272E-03 -.1327E-04 -.8958E-04 -.1356E-17  .1299E-15
 .1327E-04  .8958E-04  .1798E-04  .1272E-03  .1212E-04  .9015E-04  .1157E-15 -.1193E-14 -.4049E-03  .5624E-02
-.5256E-03 -.4478E-02 -.3664E-03 -.2493E-02 -.9807E-17 -.1961E-17  .3664E-03  .2493E-02  .5256E-03  .4478E-02
 .4049E-03 -.5624E-02
 .1214E-04  .9026E-04  .5593E-18  .7110E-17 -.1214E-04 -.9026E-04 -.1796E-04 -.1272E-03 -.1329E-04 -.8968E-04
-.1839E-17 -.3923E-17  .1329E-04  .8968E-04  .1796E-04  .1272E-03  .4054E-03 -.5608E-02  .1961E-16 -.2087E-14
-.4054E-03  .5608E-02 -.5257E-03 -.4485E-02 -.3667E-03 -.2495E-02  .7257E-16  .2471E-15  .3667E-03  .2495E-02
 .5257E-03  .4485E-02
 .1798E-04  .1272E-03  .1212E-04  .9016E-04  .6436E-18 -.1471E-17 -.1212E-04 -.9016E-04 -.1798E-04 -.1272E-03
-.1327E-04 -.8958E-04 -.1540E-17 -.6375E-17  .1327E-04  .8958E-04  .5256E-03  .4478E-02  .4049E-03 -.5624E-02
-.3138E-16 -.1726E-15 -.4049E-03  .5624E-02 -.5256E-03 -.4478E-02 -.3664E-03 -.2493E-02 0.          .1098E-15
 .3664E-03  .2493E-02
 .1329E-04  .8968E-04  .1796E-04  .1272E-03  .1214E-04  .9026E-04  .7049E-18 -.2452E-17 -.1214E-04 -.9026E-04
-.1796E-04 -.1272E-03 -.1329E-04 -.8968E-04 -.1582E-17 -.4658E-17  .3667E-03  .2495E-02  .5257E-03  .4485E-02
 .4054E-03 -.5608E-02  .7846E-17 -.1899E-14 -.4054E-03  .5608E-02 -.5257E-03 -.4485E-02 -.3667E-03 -.2495E-02
 .2158E-16  .1196E-15
-.1900E-17  .7601E-17  .1327E-04  .8958E-04  .1798E-04  .1272E-03  .1212E-04  .9016E-04  .4291E-18  .9072E-17
-.1212E-04 -.9016E-04 -.1798E-04 -.1272E-03 -.1327E-04 -.8958E-04  .3138E-16  .2864E-15  .3664E-03  .2493E-02
 .5256E-03  .4478E-02  .4049E-03 -.5624E-02  .1079E-15 -.2872E-14 -.4049E-03  .5624E-02 -.5256E-03 -.4478E-02
-.3664E-03 -.2493E-02
-.1329E-04 -.8968E-04 -.1437E-17 -.8581E-17  .1329E-04  .8968E-04  .1796E-04  .1272E-03  .1214E-04  .9026E-04
 .4904E-18  .5149E-17 -.1214E-04 -.9026E-04 -.1796E-04 -.1272E-03 -.3667E-03 -.2495E-02  .7453E-16  .3138E-15
 .3667E-03  .2495E-07  .5257E-03  .4485E-02  .4054E-03 -.5608E-02  .7846E-16 -.1161E-14 -.4054E-03  .5608E-02
-.5257E-03 -.4485E-02
-.1798E-04 -.1272E-03 -.1327E-04 -.8958E-04 -.1935E-17 -.1250E-16  .1327E-04  .8958E-04  .1798E-04  .1272E-03
 .1212E-04  .9016E-04  .9730E-18  .1618E-15 -.1212E-04 -.9016E-04 -.5256E-03 -.4478E-02 -.3664E-03 -.2493E-02
 .1020E-15  .3276E-15  .3664E-03  .2493E-02  .5256E-03  .4478E-02  .4049E-03 -.5624E-02 -.3923E-17 -.2448E-14
-.4049E-03  .5624E-02
-.1214E-04 -.9026E-04 -.1796E-04 -.1272E-03 -.1329E-04 -.8968E-04 -.1536E-17 -.4904E-18  .1329E-04  .8968E-04
 .1796E-04  .1272E-03  .1214E-04  .9026E-04  .6129E-18  .6129E-17 -.4054E-03  .5608E-02 -.5257E-03 -.4485E-02
-.3667E-03 -.2495E-02  .4511E-16  .2118E-15  .3667E-03  .2495E-02  .5257E-03  .4485E-02  .4054E-03 -.5608E-02
 .2354E-16 -.1051E-14
```

Z^{cctp}

Figure 15. Continued.

Z C(R) - C(R)

.2730E-03	-.8084E-01	.1651E-03	-.4633E-01	-.5008E-06	-.1633E-01	-.1425E-03	-.1011E-01	-.2003E-03	-.8970E-02
-.1425E-03	-.1011E-01	-.5008E-06	-.1633E-01	.1651E-03	-.4633E-01	.6231E-05	.4868E-04	.4464E-05	.3445E-04
-.6561E-07	.1392E-06	-.4953E-05	-.3401E-04	-.7078E-05	-.4808E-04	-.4953E-05	-.3401E-04	-.6561E-07	.1392E-05
.4464E-05	.3445E-04								
.1651E-03	-.4633E-01	.2737E-03	-.8079E-01	.1651E-03	-.4633E-01	-.5048E-06	-.1631E-01	-.1425E-03	-.1011E-01
-.2005E-03	-.8966E-02	-.1425E-03	-.1011E-01	-.5048E-06	-.1631E-01	.4464E-05	.3445E-04	.6238E-05	.4874E-04
.4464E-05	.3445E-04	-.6534E-07	.1392E-06	-.4953E-05	-.3401E-04	-.7086E-05	-.4813E-04	-.4953E-05	-.3401E-04
-.6534E-07	.1392E-06								
-.5008E-06	-.1633E-01	.1651E-03	-.4633E-01	.2730E-03	-.8084E-01	.1651E-03	-.4633E-01	-.5008E-06	-.1633E-01
-.1425E-03	-.1011E-01	-.2003E-03	-.8970E-02	-.1425E-03	-.1011E-01	-.6561E-07	.1392E-06	.4464E-05	.3445E-04
.6231E-05	.4868E-04	.4464E-05	.3445E-04	-.6561E-07	.1392E-06	-.4953E-05	-.3401E-04	-.7078E-05	-.4808E-04
-.4953E-05	-.3401E-04								
-.1425E-03	-.1011E-01	-.5048E-06	-.1631E-01	.1651E-03	-.4633E-01	.2737E-03	-.8079E-01	.1651E-03	-.4633E-01
-.5048E-06	-.1631E-01	-.1425E-03	-.1011E-01	-.2005E-03	-.8966E-02	-.4953E-05	-.3401E-04	-.6534E-07	.1392E-05
.4464E-05	.3445E-04	.6238E-05	.4874E-04	.4464E-05	.3445E-04	-.6534E-07	.1392E-06	-.4953E-05	-.3401E-04
-.7086E-05	-.4813E-04								
-.2003E-03	-.8970E-02	-.1425E-03	-.1011E-01	-.5008E-06	-.1633E-01	.1651E-03	-.4633E-01	.2730E-03	-.8084E-01
.1651E-03	-.4633E-01	-.5008E-06	-.1633E-01	-.1425E-03	-.1011E-01	-.7078E-05	-.4808E-04	-.4953E-05	-.3401E-04
-.6561E-07	.1392E-06	.4464E-05	.3445E-04	.6231E-05	.4868E-04	.4464E-05	.3445E-04	-.6561E-07	.1392E-05
-.4953E-05	-.3401E-04								
-.1425E-03	-.1011E-01	-.2005E-03	-.8966E-02	-.1425E-03	-.1011E-01	-.5048E-06	-.1631E-01	.1651E-03	-.4633E-01
.2737E-03	-.8079E-01	.1651E-03	-.4633E-01	-.5048E-06	-.1631E-01	-.4953E-05	-.3401E-04	-.7086E-05	-.4813E-04
-.4953E-05	-.3401E-04	-.6534E-07	.1392E-06	.4464E-05	.3445E-04	.6238E-05	.4874E-04	.4464E-05	.3445E-04
-.6534E-07	.1392E-06								
-.5008E-06	-.1633E-01	-.1425E-03	-.1011E-01	-.2003E-03	-.8970E-02	-.1425E-03	-.1011E-01	-.5008E-06	-.1633E-01
.1651E-03	-.4633E-01	.2730E-03	-.8084E-01	.1651E-03	-.4633E-01	-.6561E-07	.1392E-06	-.4953E-05	-.3401E-04
-.7078E-05	-.4808E-04	-.4953E-05	-.3401E-04	-.6561E-07	.1392E-06	.4464E-05	.3445E-04	.6231E-05	.4868E-04
.4464E-05	.3445E-04								
.1651E-03	-.4633E-01	-.5048E-06	-.1631E-01	-.1425E-03	-.1011E-01	-.2005E-03	-.8966E-02	-.1425E-03	-.1011E-01
-.5048E-06	-.1631E-01	.1651E-03	-.4633E-01	.2737E-03	-.8079E-01	.4464E-05	.3445E-04	-.6534E-07	.1392E-05
-.4953E-05	-.3401E-04	-.7086E-05	-.4813E-04	-.4953E-05	-.3401E-04	-.6534E-07	.1392E-06	.4464E-05	.3445E-04
.6238E-05	.4874E-04								
.6231E-05	.4868E-04	.4464E-05	.3445E-04	-.6561E-07	.1392E-06	-.4953E-05	-.3401E-04	-.7078E-05	-.4808E-04
-.4953E-05	-.3401E-04	-.6561E-07	.1392E-06	.4464E-05	.3445E-04	.2730E-03	-.8084E-01	.1651E-03	-.4633E-01
-.5008E-06	-.1633E-01	-.1425E-03	-.1011E-01	-.2003E-03	-.8970E-02	-.1425E-03	-.1011E-01	-.5008E-06	-.1633E-01
.1651E-03	-.4633E-01								
.4464E-05	.3445E-04	.6238E-05	.4874E-04	.4464E-05	.3445E-04	-.6534E-07	.1392E-06	-.4953E-05	-.3401E-04
-.7086E-05	-.4813E-04	-.4953E-05	-.3401E-04	-.6534E-07	.1392E-06	.1651E-03	-.4633E-01	.2737E-03	-.8079E-01
.1651E-03	-.4633E-01	-.5048E-06	-.1631E-01	-.1425E-03	-.1011E-01	-.2005E-03	-.8966E-02	-.1425E-03	-.1011E-01
-.5048E-06	-.1631E-01								
-.6561E-07	.1392E-06	.4464E-05	.3445E-04	.6231E-05	.4868E-04	.4464E-05	.3445E-04	-.6561E-07	.1392E-05
-.4953E-05	-.3401E-04	-.7078E-05	-.4808E-04	-.4953E-05	-.3401E-04	-.5008E-06	-.1633E-01	.1651E-03	-.4633E-01
.2730E-03	-.8084E-01	.1651E-03	-.4633E-01	-.5008E-06	-.1633E-01	-.1425E-03	-.1011E-01	-.2003E-03	-.8970E-02
-.1425E-03	-.1011E-01								
-.4953E-05	-.3401E-04	-.6534E-07	.1392E-05	.4464E-05	.3445E-04	.6238E-05	.4874E-04	.4464E-05	.3445E-04
-.6534E-07	.1392E-06	-.4953E-05	-.3401E-04	-.7086E-05	-.4813E-04	-.1425E-03	-.1011E-01	-.5048E-06	-.1631E-01
.1651E-03	-.4633E-01	.2737E-03	-.8079E-01	.1651E-03	-.4633E-01	-.5048E-06	-.1631E-01	-.1425E-03	-.1011E-01
-.2005E-03	-.8966E-02								
-.7078E-05	-.4808E-04	-.4953E-05	-.3401E-04	-.5561E-07	.1392E-06	.4464E-05	.3445E-04	.6231E-05	.4868E-04
.4464E-05	.3445E-04	-.6551E-07	.1392E-06	-.4953E-05	-.3401E-04	-.2003E-03	-.8970E-02	-.1425E-03	-.1011E-01
-.5008E-06	-.1633E-01	.1651E-03	-.4633E-01	.2730E-03	-.8084E-01	.1651E-03	-.4633E-01	-.5008E-06	-.1533E-01
-.1425E-03	-.1011E-01								
-.4953E-05	-.3401E-04	-.7086E-05	-.4813E-04	-.4953E-05	-.3401E-04	-.6534E-07	.1392E-06	.4464E-05	.3445E-04
.6238E-05	.4874E-04	.4464E-05	.3445E-04	-.6534E-07	.1392E-06	-.1425E-03	-.1011E-01	-.2005E-03	-.8966E-02
-.1425E-03	-.1011E-01	-.5048E-06	-.1631E-01	.1651E-03	-.4633E-01	.2737E-03	-.8079E-01	.1651E-03	-.4633E-01
-.5048E-06	-.1631E-01								
-.6561E-07	.1392E-06	-.4953E-05	-.3401E-04	-.7078E-05	-.4808E-04	-.4953E-05	-.3401E-04	-.6561E-07	.1392E-05
.4464E-05	.3445E-04	.6231E-05	.4868E-04	.4464E-05	.3445E-04	-.5008E-06	-.1633E-01	-.1425E-03	-.1011E-01
-.2003E-03	-.8970E-02	-.1425E-03	-.1011E-01	-.5008E-06	-.1633E-01	.1651E-03	-.4633E-01	.2730E-03	-.8084E-01
.1651E-03	-.4633E-01								
.4464E-05	.3445E-04	-.6534E-07	.1392E-06	-.4953E-05	-.3401E-04	[illegible]	-.4813E-04	-.4953E-05	-.3401E-04
-.6534E-07	.1392E-06	.4464E-05	.3445E-04	.5238E-05	.4874E-04	[illegible]	-.4633E-01	-.5048E-06	-.1631E-01
-.1425E-03	-.1011E-01	-.2005E-03	-.8966E-02	-.1425E-03	-.1011E-01	-.5048E-06	-.1631E-01	.1651E-03	-.4633E-01
.2737E-03	-.8079E-01								

Z^{ccpp}

Figure 15. Concluded.

```
OLD Y MATRIX PARAMETERS:
                        NMODE   NP     NC    NPH     NE     NW    NPW
                          4     19      0     0      0      0      0

      MODE NO. OF ADDITIONS:       CAPS       WIRES
                                     0          0

NEW ADDITIONS:
                        NC1   NPR1    NE1    NW1    NPW1    NJ1      User-specified input for adding caps
                         2      5      0      0      0     0

CAPS ADDED TO MATRIX

 T AND Z SURFACE IMPEDANCE LOADING (COMPLEX)

  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
                                                                                      Surface loadings are user specified
  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
NEW Y MATRIX PARAMETERS:
                        NMODE   NP     NC    NPH     NE     NW    NPW
                          4     19      2     5      0      0      0

      MODE NO. OF ADDITIONS:       CAPS       WIRES
                                     4          0

MINIMUM PROGRAM DIMENSIONS ARE AS FOLLOWS:
     PI        Q        R        S       YI       W1       W2,LOADWGHT
  12544     3584     3584     1024     1024      112       32

 CAP IMPEDANCE ADDED


Y1
   .1344E-02 -.6463      .3405E-02 -.3913       .1629E-02  .22        -.1759E-02  .1558E-01 -.2151E-02 -.4418
  -.1759E-02  .1558E-01  .1629E-02  .2249       .3405E-02 -.39
   .3405E-02 -.3913      .1318E-02 -.6481       .3405E-02 -.39         .1651E-02  .2269     -.1759E-02  .1558E-01
  -.2169E-02 -.4441     -.1759E-02  .1558E-01   .1651E-02  .22
   .1629E-02  .2249      .3405E-02 -.3913       .1344E-02 -.64         .3405E-02 -.3913      .1629E-02  .2249
  -.1759E-02  .1558E-01 -.2151E-02 -.4418      -.1759E-02  .15  E-01
  -.1759E-02  .1558E-01  .1651E-02  .2269       .3405E-02 -.39         .1318E-02 -.6481      .3405E-02 -.3913
   .1651E-02  .2269     -.1759E-02  .1558E-01  -.2169E-02 -.44
  -.2151E-02 -.4418     -.1759E-02  .1558E-01   .1629E-02  .22         .3405E-02 -.3913      .1344E-02 -.6463
   .3405E-02 -.3913      .1629E-02  .2249      -.1759E-02  .15  E-01
  -.1759E-02  .1558E-01 -.2169E-02 -.4441      -.1759E-02  .15  E-01   .1651E-02  .2269      .3405E-02 -.3913
   .1318E-02 -.6481      .3405E-02 -.3913       .1651E-02  .22
   .1629E-02  .2249     -.1759E-02  .1558E-01  -.2151E-02 -.44        -.1759E-02  .1558E-01  .1629E-02  .2249
   .3405E-02 -.3913      .1344E-02 -.6463       .3405E-02 -.39
   .3405E-02 -.3913      .1651E-02  .2269      -.1759E-02  .15  E-01  -.2169E-02 -.4441     -.1759E-02  .1558E-01
   .1651E-02  .2269      .3405E-02 -.3913       .1318E-02 -.64
```

Figure 16. Partial output of BOTINVA for Problems 2a-2c when caps are added to the system matrix.

NW	NPW	NJ
1	9	1

WIRE COORDINATES / JUNCTION PARAMETERS

	IW	XW	YW	ZW	IJ	RADJ	UXJ	UYJ	UZJ
WIRE 1 RADW= .0011									
	1	.0381	.0381	0.0000	1	.0450	0.0000	1.0000	0.0000
	2	.0381	.0540	0.0000					
	3	.0381	.0698	0.0000					
	4	.0381	.0857	0.0000					
	5	.0381	.1016	0.0000					
	6	.0381	.1175	0.0000					
	7	.0381	.1334	0.0000					
	8	.0381	.1492	0.0000					
	9	.0381	.1651	0.0000					

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Figure 17a. Output of wire input data for Problem 2a.

NW	NPW	NJ
2	18	2

WIRE COORDINATES / JUNCTION PARAMETERS

	IW	XW	YW	ZW	IJ	RADJ	UXJ	UYJ	UZJ
WIRE 1 RADW= .0011									
	1	.0381	.0381	0.0000	1	.0450	0.0000	1.0000	0.0000
	2	.0381	.0540	0.0000					
	3	.0381	.0698	0.0000					
	4	.0381	.0857	0.0000					
	5	.0381	.1016	0.0000					
	6	.0381	.1175	0.0000					
	7	.0381	.1334	0.0000					
	8	.0381	.1492	0.0000					
	9	.0381	.1651	0.0000					
WIRE 2 RADW= .0011									
	10	.0381	.0381	.1270	2	.0450	0.0000	1.0000	0.0000
	11	.0381	.0540	.1270					
	12	.0381	.0698	.1270					
	13	.0381	.0857	.1270					
	14	.0381	.1016	.1270					
	15	.0381	.1175	.1270					
	16	.0381	.1334	.1270					
	17	.0381	.1492	.1270					
	18	.0381	.1651	.1270					

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Figure 17b. Output of wire input data for Problem 2b.

NW	NPW	NJ
1	13	2

WIRE COORDINATES / JUNCTION PARAMETERS

	IW	XW	YW	ZW	IJ	RADJ	UXJ	UYJ	UZJ
WIRE 1 RADW= .0011									
	1	.0381	.0381	0.0000	1	.0450	0.0000	1.0000	0.0000
	2	.0381	.0475	0.0000					
	3	.0381	.0570	0.0000					
	4	.0381	.0570	.0159					
	5	.0381	.0570	.0318					
	6	.0381	.0570	.0476					
	7	.0381	.0570	.0635					
	8	.0381	.0570	.0794					
	9	.0381	.0570	.0953					
	10	.0381	.0570	.1111					
	11	.0381	.0570	.1270					
	12	.0381	.0475	.1270					
	13	.0381	.0381	.1270	2	.0450	0.0000	1.0000	0.0000

Figure 17c. Output of wire input data for Problem 2c.

```
Z WIRE - WIRE
  3.020        -756.4  2.980   368.2  2.843   46.13
  2.980         368.3  3.030  -755.5  2.980  368.3    Zww
  2.843         46.13  2.980   368.2  3.020 -756.4
Z JUNC - WIRE
  1.519         366.6
  1.486         41.52                                 Zjw
  1.404         7.829
Z WIRE - JUNC
  1.519         366.6  1.486   41.52  1.404   7.829   Zwj
Z JUNC - JUNC
  1.254        -374.2                                 Zjj
```

Figure 18. Partial output of BOTZWW for Problem 2a.

```
M= -3
NUMBER OF INTEGRATIONS AND AVERAGE NUMBER OF POINTS PER INTEGRATION (G1 AND G2, RESPECTIVELY)
    144   11.4           144   38.1

Z S(T) - WIRE
 .1127E-01   1.710       .1757E-14   .5021E-15  -.1127E-01  -1.710      -.1534E-01  -.3355      -.9980E-02  -.7649E-01
-.1255E-15   .2511E-15   .9980E-02   .7649E-01   .1534E-01   .3355
 .1104E-01   .3479      -.7532E-15   .2322E-14  -.1104E-01  -.3479      -.1382E-01  -.1101      -.8826E-02  -.2136E-01
-.2511E-15   .1255E-15   .8826E-02   .2136E-01   .1382E-01   .1101
 .9833E-02   .8043E-01   .3766E-15   .9415E-15  -.9833E-02  -.8043E-01  -.1215E-01  -.2657E-01  -.7448E-02  -.1838E-02
-.6277E-16   .1255E-15   .7448E-02   .1838E-02   .1215E-01   .2657E-01

Z S(Z) - WIRE
 1.273      -.1246E-01   2.817      -.9672E-02   1.273      -.1246E-01   .3511      -.1824E-01   .1645      -.2353E-01
 .1279      -.2563E-01   .1645      -.2353E-01   .3511      -.1824E-01
 .3623      -.1998E-01   .6206      -.1993E-01   .3623      -.1998E-01   .1227      -.2456E-01   .5494E-01  -.2859E-01
 .4156E-01  -.3008E-01   .5494E-01  -.2859E-01   .1227      -.2456E-01
 .1088      -.2592E-01   .1684      -.2439E-01   .1088      -.2592E-01   .4243E-01  -.2905E-01   .1895E-01  -.3144E-01
 .1366E-01  -.3223E-01   .1895E-01  -.3144E-01   .4243E-01  -.2905E-01

Z S(T) - JUNC
 .5839E-02   .4824      -.7804E-08  -.1767E-12  -.5839E-02  -.4824      -.7599E-02  -.2888      -.5168E-02  -.5430E-01
 .7109E-11   .1634E-12   .5168E-02   .5430E-01   .7599E-02   .2888

Z S(Z) - JUNC
 .9546      -.7883E-02   .5376      -.6552E-02   .9546      -.7883E-02   .2676      -.1105E-01   .1057      -.1389E-01
 .7769E-01  -.1498E-01   .1057      -.1389E-01   .2676      -.1105E-01
```

$Z^{sw,t}_{-3}$

$Z^{sw,z}_{-3}$

$Z^{sj,t}_{-3}$

$Z^{sj,z}_{-3}$

Figure 19. Partial output of ROTZSW for Problem 2a.

```
Z C(T) - WIRE
 -.6907E-02 -.1842E-01  .5550E-15 0.           .6907E-02  .1842E-01  .1034E-01  .2488E-01  .7713E-02  .1682E-01
  .1381E-14 -.1506E-14 -.7713E-02 -.1682E-01 -.1034E-01 -.2488E-01 -.6907E-02 -.1842E-01  .5550E-15 0.
  .6907E-02  .1842E-01  .1034E-01  .2488E-01  .7713E-02  .1682E-01  .1381E-14 -.1506E-14 -.7713E-02 -.1682E-01
 -.1034E-01 -.2488E-01
 -.6954E-02 -.1647E-01  .6277E-15 -.1506E-14  .6954E-02  .1647E-01  .1061E-01  .2184E-01  .8016E-02  .1447E-01
  .3138E-15 -.5021E-15 -.8016E-02 -.1447E-01 -.1061E-01 -.2184E-01 -.6954E-02 -.1647E-01  .6277E-15 -.1506E-14
  .6954E-02  .1647E-01  .1061E-01  .2184E-01  .8016E-02  .1447E-01  .3138E-15 -.5021E-15 -.8016E-02 -.1447E-01
 -.1061E-01 -.2184E-01
 -.7031E-02 -.1409E-01 -.6904E-15 -.1757E-14  .7031E-02  .1409E-01  .1084E-01  .1832E-01  .8237E-02  .1187E-01
  .2260E-14 -.5021E-15 -.8237E-02 -.1187E-01 -.1084E-01 -.1832E-01 -.7031E-02 -.1409E-01 -.6904E-15 -.1757E-14
  .7031E-02  .1409E-01  .1084E-01  .1832E-01  .8237E-02  .1187E-01  .2260E-14 -.5021E-15 -.8237E-02 -.1187E-01
 -.1084E-01 -.1832E-01
```

$Z^{cw,t}$

```
Z C(R) - WIRE
 -.2773E-02 -.7166E-02 -.3743E-02 -.1019E-01 -.2773E-02 -.7166E-02 -.2165E-03 -.2167E-03  .2629E-02  .6265E-02
  .3889E-02  .8821E-02  .2629E-02  .6265E-02 -.2165E-03 -.2167E-03 -.2773E-02 -.7166E-02 -.3743E-02 -.1019E-01
 -.2773E-02 -.7166E-02 -.2165E-03 -.2167E-03  .2629E-02  .6265E-02  .3889E-02  .8821E-02  .2629E-02  .6265E-02
 -.2165E-03 -.2167E-03
 -.2886E-02 -.6461E-02 -.3839E-02 -.9219E-02 -.2886E-02 -.6461E-02 -.2949E-03 -.2480E-03  .2675E-02  .5367E-02
  .4007E-02  .7526E-02  .2675E-02  .5367E-02 -.2949E-03 -.2480E-03 -.2886E-02 -.6461E-02 -.3839E-02 -.9219E-02
 -.2886E-02 -.6461E-02 -.2949E-03 -.2480E-03  .2675E-02  .5367E-02  .4007E-02  .7526E-02  .2675E-02  .5367E-02
 -.2949E-03 -.2480E-03
 -.2992E-02 -.5551E-02 -.3946E-02 -.7962E-02 -.2992E-02 -.5551E-02 -.3517E-03 -.2309E-03  .2714E-02  .4410E-02
  .4094E-02  .6140E-02  .2714E-02  .4410E-02 -.3517E-03 -.2309E-03 -.2992E-02 -.5551E-02 -.3946E-02 -.7962E-02
 -.2992E-02 -.5551E-02 -.3517E-03 -.2309E-03  .2714E-02  .4410E-02  .4094E-02  .6140E-02  .2714E-02  .4410E-02
 -.3517E-03 -.2309E-03
```

$Z^{cw,\rho}$

```
Z C(T) - JUNC
 0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 0.         0.
```

$Z^{cj,t}$

```
Z C(R) - JUNC
 0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 0.         0.
```

$Z^{cj,\rho}$

Figure 20. Partial output of BOTZCW for Problem 2a.

```
OLD Y MATRIX PARAMETERS:
                        NMODE   NP     NC    NPR     NE     NW    NPW     NJ
                          4     19      2     5       0      0     0       0

      MODE NO. OF ADDITIONS:       CAPS      WIRES
                                     4         0

NEW ADDITIONS:
                        NC1   NPR1    NE1    NW1    NPW1     NJ1
                         0      0      0      1      9     1
```

} User-specified input for adding the wire

```
WIRES ADDED TO MATRIX

NEW Y MATRIX PARAMETERS:
                        NMODE   NP     NC    NPR     NE     NW    NPW     NJ
                          4     19      2     5       0      1     9       1

      MODE NO. OF ADDITIONS:       CAPS      WIRES
                                     4         5

MINIMUM PROGRAM DIMENSIONS ARE AS FOLLOWS:
     PI         Q          R          S        YI        W1       W2+LOAD&WGHT
   20736       576        576         16      1024       144           4


  M= -3   N= -3

Y1
  .1282E-02 -.6461      .3405E-02 -.3913      .1691E-02  .2247     -.1683E-02  .1545E-01 -.2151E-02 -.4419
 -.1759E-02  .1558E-01  .1630E-02  .2249      .3329E-02 -.3911
  .3405E-02 -.3913      .1318E-02 -.6481      .3405E-02 -.3913      .1651E-02  .2269     -.1759E-02  .1558E-01
 -.2169E-02 -.4441     -.1759E-02  .1558E-01  .1651E-02  .2269
  .1691E-02  .2247      .3405E-02 -.3913      .1282E-02 -.6461      .3329E-02 -.3911      .1630E-02  .2249
 -.1759E-02  .1558E-01 -.2151E-02 -.4419     -.1683E-02  .1545E-01
 -.1683E-02  .1545E-01  .1651E-02  .2269      .3329E-02 -.3911      .1228E-02 -.6480      .3381E-02 -.3910
  .1651E-02  .2269     -.1735E-02  .1534E-01 -.2079E-02 -.4442
 -.2151E-02 -.4419     -.1759E-02  .1558E-01  .1630E-02  .2249      .3381E-02 -.3910      .2498E-02 -.6450
  .3405E-02 -.3913      .4755E-03  .2236     -.1735E-02  .1534E-01
 -.1759E-02  .1558E-01 -.2169E-02 -.4441     -.1759E-02  .1558E-01  .1651E-02  .2269      .3405E-02 -.3913
  .1318E-02 -.6481      .3405E-02 -.3913      .1651E-02  .2269
  .1630E-02  .2249     -.1759E-02  .1558E-01 -.2151E-02 -.4419     -.1735E-02  .1534E-01  .4755E-03  .2236
  .3405E-02 -.3913      .2498E-02 -.6450      .3381E-02 -.3910
  .3329E-02 -.3911      .1651E-02  .2269     -.1683E-02  .1545E-01 -.2079E-02 -.4442     -.1735E-02  .1534E-01
  .1651E-02  .2269      .3381E-02 -.3910      .1228E-02 -.6480
```

Figure 21. Partial output of BOTINVA for Problem 2a when the wire is added to the capped BOT.

```
NUMBER OF SLOT ANTENNAS =  0

   WIRE VOLTAGES
 WIRE INDEX              VOLTAGE
     4             1.0000    0.0000

NUMBER OF FIXED ANGLES =  4
NUMBER OF ANGLES PER FIXED ANGLE =  37

FIXED ANGLE    CODE      VARIABLE ANGLE RANGE
    90.0         1            0.0 -    180.0
     0.0         1            0.0 -    180.0
   -90.0         1            0.0 -    180.0
    90.0         2          -90.0 -     90.0
THE Y MATRIX CONTAINS THE FOLLOWING ADDITIONS ( 0 IF NOT INCLUDED, OR CORRESPONDING MODE NUMBER IF PRESENT):

         CAPS   4
         WIRES  5

  81 SUBMATRICES READ

TOTAL POWER(DB) =  -17.82
```

Figure 22. Partial output of BOTRA for Problem 2a.

PHI	THETA	POWER(DB) θ	POWER(DB) ϕ
90.0	0.0	-.68	-147.27
90.0	5.0	.24	-147.26
90.0	10.0	.95	-147.26
90.0	15.0	1.51	-147.28
90.0	20.0	1.93	-147.33
90.0	25.0	2.25	-147.41
90.0	30.0	2.46	-147.51
90.0	35.0	2.57	-147.66
90.0	40.0	2.58	-147.83
90.0	45.0	2.47	-148.04
90.0	50.0	2.21	-148.29
90.0	55.0	1.78	-148.56
90.0	60.0	1.11	-148.84
90.0	65.0	.12	-149.13
90.0	70.0	-1.31	-149.41
90.0	75.0	-3.39	-149.65
90.0	80.0	-6.61	-149.84
90.0	85.0	-12.44	-149.96
90.0	90.0	-149.63	-150.02
90.0	95.0	-12.44	-149.96
90.0	100.0	-6.61	-149.84
90.0	105.0	-3.39	-149.65
90.0	110.0	-1.31	-149.41
90.0	115.0	.12	-149.13
90.0	120.0	1.11	-148.84
90.0	125.0	1.78	-148.56
90.0	130.0	2.21	-148.29
90.0	135.0	2.47	-148.04
90.0	140.0	2.58	-147.83
90.0	145.0	2.57	-147.65
90.0	150.0	2.46	-147.51
90.0	155.0	2.25	-147.41
90.0	160.0	1.93	-147.33
90.0	165.0	1.51	-147.28
90.0	170.0	.95	-147.26
90.0	175.0	.24	-147.26
90.0	180.0	-.68	-147.27

Figure 22. Concluded.

```
Z WIRE - WIRE
 3.020   -756.4    2.980    368.2    2.843    46.13    1.725   -1.761    1.697   -1.486
 1.604   -.9323    3.030   -755.5    2.980    368.3    1.697   -1.486    1.731   -1.766
 2.980    368.3    2.980    368.2    3.020   -756.4    1.604   -.9323    1.697   -1.486
 1.697   -1.486    1.697   -1.486    1.604   -.9323    3.020   -756.4    2.980    368.2
 2.843    46.13    1.731   -1.766    1.697   -1.486    2.980    368.3    3.030   -755.5
 1.725   -1.761    1.697   -1.486    1.725   -1.761    2.843    46.13    2.980    368.2
 1.725   -1.761
 2.843    46.13
 1.697   -1.486
 2.980    368.3
 1.604   -.9323
 3.020   -756.4

Z JUNC - WIRE
 1.519    366.6    .8693   -.9007
 1.486    41.52    .8470   -.6253
 1.404    7.829    .7921   -.3345
 .8693   -.9007    1.519    366.6
 .8470   -.6253    1.486    41.52
 .7921   -.3345    1.404    7.829

Z WIRE - JUNC
 1.519    366.6    1.486    41.52    1.404    7.829    .8693   -.9007    .8470   -.6253
 .7921   -.3345    .8470   -.6253    .7921   -.3345    1.519    366.6    1.486    41.52
 .8693   -.9007
 1.404    7.829

Z JUNC - JUNC
 1.254   -374.2    .4412   -.4770
 .4412   -.4770    1.254   -374.2
```

Z^{ww}

Z^{jw}

Z^{wj}

Z^{jj}

Figure 23. Partial output of BOTZWW for Problem 2b.

```
M= -3

NUMBER OF INTEGRATIONS AND AVERAGE NUMBER OF POINTS PER INTEGRATION (G1 AND G2, RESPECTIVELY)
    306  12.5            306  37.2

Z S(T) - WIRE
  .1127E-01   1.710       .1757E-14   .5021E-15  -.1127E-01  -1.710      -.1534E-01 -.3355      -.9980E-02 -.7649E-01
 -.1255E-15   .2511E-15   .9980E-02   .7649E-01   .1534E-01   .3355
  .1104E-01   .3479      -.7532E-15   .2322E-14  -.1104E-01  -.3479      -.1382E-01 -.1101      -.8826E-02 -.2136E-01
 -.2511E-15   .1255E-15   .8826E-02   .2136E-01   .1382E-01   .1101
  .9833E-02   .8043E-01   .3766E-15   .9415E-15  -.9833E-02  -.8043E-01  -.1215E-01 -.2657E-01 -.7448E-02 -.1838E-02
 -.6277E-16   .1255E-15   .7448E-02   .1838E-02   .1215E-01   .2657E-01
  1.750       .4604E-01   .1205E-13   .7030E-14  -1.750      -.4604E-01  -.3901      -.6176E-01 -.1143      -.4089E-01
 -.5021E-15  -.5021E-15   .1143       .4089E-01   .3901       .6176E-01
  .3805       .4718E-01  -.2008E-14  -.5021E-14  -.3805      -.4718E-01  -.1567      -.5918E-01 -.5507E-01 -.3679E-01
  0.          .5021E-15   .5507E-01   .3679E-01   .1567       .5918E-01
  .1078       .4423E-01   .1506E-14   .3013E-14  -.1078      -.4423E-01  -.6844E-01 -.5213E-01 -.3316E-01 -.3052E-01
  0.          .1004E-14   .3316E-01   .3052E-01   .6844E-01   .5213E-01
```

$Z^{sw,t}_{-3}$

```
Z S(Z) - WIRE
  1.273      -.1246E-01   2.817      -.9672E-02   1.273      -.1246E-01   .3511      -.1824E-01  .1645      -.2353E-01
  .1279      -.2563E-01   .1645      -.2353E-01   .3511      -.1824E-01
  .3623      -.1998E-01   .6206      -.1803E-01   .3623      -.1998E-01   .1227      -.2456E-01  .5494E-01 -.2859E-01
  .4156E-01  -.3008E-01   .5694E-01  -.2859E-01   .1227      -.2456E-01
  .1088      -.2592E-01   .1684      -.2439E-01   .1088      -.2592E-01   .4243E-01  -.2905E-01  .1895E-01 -.3144E-01
  .1366E-01  -.3223E-01   .1895E-01  -.3144E-01   .4243E-01  -.2905E-01
  .7552E-01  -1.218       .6171E-01  -2.770       .7552E-01  -1.219       .1047      -.2837      .1289      -.9138E-01
  .1377      -.5417E-01   .1289      -.9138E-01   .1047      -.2837
  .1142      -.2895       .1059      -.5478       .1142      -.2895       .1310      -.5451E-01  .1442       .2849E-02
  .1488       .1228E-01   .1442       .3849E-02   .1310      -.5451E-01
  .1371      -.3972E-01   .1337      -.9249E-01   .1371      -.3972E-01   .1434       .8383E-02  .1474       .1209E-01
  .1484       .8920E-02   .1474       .1209E-01   .1434       .8383E-02
```

$Z^{sw,z}_{-3}$

```
Z S(T) - JUNC
  .5839E-02   .4826      -.7804E-08  -.1767E-12  -.5839E-02  -.4826      -.7599E-02 -.2888      -.5168E-02 -.5430E-01
  .7109E-11   .1634E-12   .5168E-02   .5430E-01   .7599E-02   .2888
  .5042       .2277E-01  -.9450E-12   .7806E-08  -.5042      -.2277E-01  -.3184      -.3066E-01 -.7479E-01 -.2045E-01
  .3101E-12  -.7623E-11   .7479E-01   .2045E-01   .3184       .3066E-01
```

$Z^{sj,t}_{-3}$

```
Z S(Z) - JUNC
  .9546      -.7883E-02   .5376      -.6552E-02   .9546      -.7883E-02   .2676      -.1105E-01  .1057      -.1389E-01
  .7769E-01  -.1498E-01   .1057      -.1389E-01   .2676      -.1105E-01
  .4369E-01  -.9383       .3583E-01  -.5267       .4369E-01  -.9383       .6018E-01  -.2416      .7401E-01 -.7374E-01
  .7005E-01  -.4421E-01   .7401E-01  -.7374E-01   .6018E-01  -.2416
```

$Z^{sj,z}_{-3}$

Figure 24. Partial output of BOTZSW for Problem 2b.

```
Z C(T) - WIRE
-.6907E-02 -.1842E-01  .4550E-15 0.          .6907E-02  .1842E-01  .1034E-01  .2488E-01  .7713E-02  .1682E-01
 .1381E-14 -.1506E-14 -.7713E-02 -.1682E-01 -.1034E-01 -.2488E-01 -.6907E-02 -.1842E-01  .4550E-15 0.
 .6907E-02  .1842E-01  .1034E-01  .2488E-01  .7713E-02  .1682E-01  .1381E-14 -.1506E-14 -.7713E-02 -.1682E-01
-.1034E-01 -.2488E-01
-.6954E-02 -.1647E-01  .6277E-15 -.1506E-14  .6954E-02  .1647E-01  .1061E-01  .2184E-01  .8016E-02  .1447E-01
 .3138E-15 -.5021E-15 -.8016E-02 -.1447E-01 -.1061E-01 -.2184E-01 -.6954E-02 -.1647E-01  .6277E-15 -.1506E-14
 .6954E-02  .1647E-01  .1061E-01  .2184E-01  .8016E-02  .1447E-01  .3138E-15 -.5021E-15 -.8016E-02 -.1447E-01
-.1061E-01 -.2184E-01
-.7031E-02 -.1409E-01 -.6904E-15 -.1757E-14  .7031E-02  .1409E-01  .1084E-01  .1832E-01  .8237E-02  .1187E-01
 .2260E-14 -.5021E-15 -.8237E-02 -.1187E-01 -.1084E-01 -.1832E-01 -.7031E-02 -.1409E-01 -.6904E-15 -.1757E-14
 .7031E-02  .1409E-01  .1084E-01  .1832E-01  .8237E-02  .1187E-01  .2260E-14 -.5021E-15 -.8237E-02 -.1187E-01
-.1084E-01 -.1832E-01
 .2511E-01 -.1449E-01 -.6277E-14  .1381E-14 -.2511E-01  .1449E-01 -.3322E-01  .1898E-01 -.2194E-01  .1300E-01
 .6025E-14  .2008E-14  .2194E-01 -.1300E-01  .3322E-01 -.1899E-01 -.1368E-01  .3274E-02  .3766E-15 -.9415E-15
 .1368E-01 -.3274E-02  .1849E-01 -.5135E-02  .1305E-01 -.3982E-02  .6277E-15 -.5021E-15 -.1305E-01  .3982E-02
-.1889E-01  .5135E-02
 .2343E-01 -.6826E-02 0.          .7532E-15 -.2343E-01  .6826E-02 -.2999E-01  .1151E-01 -.1910E-01  .9365E-02
 .5021E-15  .2762E-14  .1910E-01 -.9365E-02  .2999E-01 -.1151E-01 -.1290E-01  .3799E-02 -.7532E-15 -.2197E-15
 .1290E-01 -.3799E-02  .1760E-01 -.6039E-02  .1201E-01 -.4721E-02 -.1255E-15 -.6277E-15 -.1201E-01  .4721E-02
-.1760E-01  .6039E-02
 .2094E-01 -.3821E-02  .2008E-14  .3766E-15 -.2094E-01  .3821E-02 -.2580E-01  .9170E-02 -.1573E-01  .8465E-02
 .3640E-14 -.2511E-15  .1573E-01 -.8465E-02  .2580E-01 -.9170E-02 -.1178E-01  .4452E-02 -.7532E-15 -.1569E-15
 .1178E-01 -.4452E-02  .1585E-01 -.7053E-02  .1064E-01 -.5487E-02  .7532E-15 -.1318E-14 -.1064E-01  .5487E-02
-.1585E-01  .7053E-02
```

$Z^{cw,t}$

Figure 25. Partial output of BOTZCW for Problem 2b.

```
OLD Y MATRIX PARAMETERS:
                 NMODE   NP      NC      NPR      NE      NW      NPW      NJ
                   4     19       2       5        0       0       0        0

     MODE NO. OF ADDITIONS:          CAPS         WIRES
                                       4             0

NEW ADDITIONS:
                 NC1    NPR1     NE1      NW1     NPW1      NJ1
                  0       0       0        2       18        2

WIRES ADDED TO MATRIX

NEW Y MATRIX PARAMETERS:
                 NMODE   NP      NC      NPR      NE      NW      NPW      NJ
                   4     19       2       5        0       2       18       2

     MODE NO. OF ADDITIONS:          CAPS         WIRES
                                       4             5

MINIMUM PROGRAM DIMENSIONS ARE AS FOLLOWS:
    PI         Q         R         S        Y1        W1       W2,LOADLWGHT
  20736      1152      1152       64      1024       144          8
```

User-specified input for adding the wires

Figure 26. Partial output of BOTINVA for Problem 2b when wires are added to the capped BOT.

```
NUMBER OF SLOT ANTENNAS =  0

   WIRE VOLTAGES

 WIRE INDEX              VOLTAGE
    7             1.0000       0.0000

NUMBER OF FIXED ANGLES =  4

NUMBER OF ANGLES PER FIXED ANGLE =  37

FIXED ANGLE    CODE      VARIABLE ANGLE RANGE

   90.0          1           0.0 -   180.0
    0.0          1           0.0 -   180.0
  -90.0          1           0.0 -   180.0
   90.0          2         -90.0 -    90.0

THE Y MATRIX CONTAINS THE FOLLOWING ADDITIONS ( 0 IF NOT INCLUDED, OR CORRESPONDING MODE NUMBER IF PRESENT):

        CAPS   4
        WIRES  5

   81 SUBMATRICES READ

 TOTAL POWER(DB) =  -18.75
```

Figure 27. Partial output of BOTRA for Problem 2b.

PHI	THETA	POWER(DB) θ	POWER(DB) φ
90.0	0.0	-7.98	-154.57
90.0	5.0	-7.01	-154.73
90.0	10.0	-5.85	-155.14
90.0	15.0	-4.78	-155.77
90.0	20.0	-3.92	-156.69
90.0	25.0	-3.27	-157.98
90.0	30.0	-2.84	-159.77
90.0	35.0	-2.64	-162.32
90.0	40.0	-2.66	-166.10
90.0	45.0	-2.94	-170.93
90.0	50.0	-3.51	-168.92
90.0	55.0	-4.45	-163.86
90.0	60.0	-5.86	-160.29
90.0	65.0	-7.96	-157.71
90.0	70.0	-11.18	-155.72
90.0	75.0	-16.50	-154.12
90.0	80.0	-21.02	-152.77
90.0	85.0	-14.42	-151.60
90.0	90.0	-9.81	-150.55
90.0	95.0	-6.84	-149.59
90.0	100.0	-4.70	-148.70
90.0	105.0	-3.01	-147.85
90.0	110.0	-1.58	-147.06
90.0	115.0	-.31	-146.33
90.0	120.0	.86	-145.66
90.0	125.0	1.91	-145.06
90.0	130.0	2.84	-144.53
90.0	135.0	3.63	-144.07
90.0	140.0	4.27	-143.68
90.0	145.0	4.75	-143.36
90.0	150.0	5.08	-143.11
90.0	155.0	5.25	-142.91
90.0	160.0	5.29	-142.75
90.0	165.0	5.19	-142.64
90.0	170.0	4.95	-142.56
90.0	175.0	4.60	-142.51
90.0	180.0	4.11	-142.49

Figure 27. Concluded

```
Z WIRE - WIRE
 1.034    -855.4     1.514     310.5     1.469     37.23     1.381     6.874     .5083     1.939    Zww
 1.512     318.9     3.020    -756.4     2.975     369.2     2.843     46.22     1.373     6.927
 1.467     37.73     2.975     369.1     3.020    -756.6     2.975     368.2     1.462     37.63
 1.378     6.952     2.843     46.21     2.975     368.1     3.020    -756.4     1.508     319.8
 .5081     1.938     1.377     6.853     1.464     37.25     1.509     311.3     1.029    -856.0

Z JUNC - WIRE                                                                                       Zjw
 .2777           507.4     .1719          -.2193
-.1024E-01       78.55     .2688E-01      -.1991
-.1934E-01       3.318     .1947E-01      -3.343
-.2700E-01       .1994     .1005E-01      -78.75
-.1718           .2189    -.2776          -507.2

Z WIRE - JUNC                                                                                       Zwj
 .2777     507.4    -.1024E-01   78.55    -.1934E-01   3.318    -.2700E-01   .1994    -.1718   .2189
 .1719    -.2193     .2688E-01  -.1991     .1947E-01  -3.343     .1005E-01  -78.75   -.2776  -507.2

Z JUNC - JUNC                                                                                       Zjj
 .4517    -544.3     .1524    -.1763
 .1524    -.1763     .4517    -544.3
```

Figure 28. Partial output of BOTZWW for Problem 2c.

```
M= -3

NUMBER OF INTEGRATIONS AND AVERAGE NUMBER OF POINTS PER INTEGRATION (G1 AND G2, RESPECTIVELY)
    216  15.9          216  51.4

Z S(T) - WIRE
  .8820        1.395       .2008E-13  .2611E-13 -.8820        -1.395       -.2312       -.2337       -.5762E-01 -.5409E-01
  .6277E-15   .6277E-15   .5762E-01  .5409E-01  .2312         .2337
  .6754        1.605       .4017E-14  .1205E-13 -.6754        -1.605       -.1791       -.3951       -.4531E-01 -.8563E-01
 -.2511E-15 -.2511E-15   .4531E-01  .8563E-01  .1791         .3951
 -1.228        1.223      -.1858E-13  .2711E-13  1.228        -1.223        .3021       -.2977        .6563E-01 -.6229E-01
 -.1004E-14 -.7532E-15  -.6563E-01  .6229E-01 -.3021         .2977
 -1.600       -.6845      -.1607E-13 -.1331E-13  1.600         .6845        .3917        .1883        .8456E-01  .5126E-01
  .5021E-15 -.5021E-15  -.8456E-01 -.5126E-01 -.3917        -.1883
 -1.401       -.8950      -.1205E-13 -.1205E-13  1.401         .8950        .2458        .2503        .6375E-01  .7049E-01
 -.1506E-14 -.2008E-14  -.6375E-01 -.7049E-01 -.2458        -.2503
```

Figure 28. Partial output of BOTZSW for Problem 2c.

```
Z C(T) - WIRE
 -.4416E-02 -.7743E-02 -.5649E-15  .1004E-14  .4416E-02  .7743E-02  .6280E-02  .1042E-01  .4474E-02  .7030E-02
 -.1412E-14  .7532E-15 -.4474E-02 -.7030E-02 -.6280E-02 -.1042E-01  .2100E-03 -.4464E-02  .6277E-15  .1004E-14
 -.2100E-03  .4464E-02 -.8823E-04  .6223E-02  .7981E-04  .4338E-02  .1946E-14 -.2385E-14 -.7981E-04 -.4338E-02
  .8823E-04 -.6223E-02
 -.4903E-02 -.5939E-02 -.1632E-14 -.2511E-15  .4903E-02  .5939E-02  .6759E-02  .7635E-02  .4670E-02  .4922E-02
 -.4896E-14 -.5021E-15 -.4670E-02 -.4922E-02 -.6759E-02 -.7635E-02  .4117E-02  .1401E-02  .1632E-14 -.1381E-14
 -.4117E-02 -.1401E-02 -.5657E-02 -.1726E-02 -.3896E-02 -.1054E-02  .2008E-14 -.2260E-14  .3896E-02  .1054E-02
  .5657E-02  .1726E-02
 -.4931E-02 -.9990E-02 -.2511E-14  .1255E-15  .4931E-02  .9990E-02  .6804E-02  .1266E-01  .4706E-02  .8072E-02
 -.1506E-14  .2511E-15 -.4706E-02 -.8072E-02 -.6804E-02 -.1266E-01  .3452E-02  .7294E-04 -.1130E-14 -.1067E-14
 -.3452E-02 -.7294E-04 -.4731E-02  .4322E-04 -.3250E-02  .1279E-03  .1381E-14 -.1883E-14  .3250E-02 -.1279E-03
  .4731E-02 -.4322E-04
 -.4681E-02 -.1697E-01  .2008E-14 -.6904E-15  .4681E-02  .1697E-01  .6464E-02  .2076E-01  .4475E-02  .1284E-01
 -.4017E-14 -.3640E-14 -.4475E-02 -.1284E-01 -.6464E-02 -.2076E-01  .2687E-02 -.8303E-03  .1255E-15 -.1193E-14
 -.2687E-02  .8303E-03 -.3668E-02  .1249E-02 -.2509E-02  .9352E-03 -.6277E-15 -.2887E-14  .2509E-02 -.9352E-03
  .3668E-02 -.1249E-02
 -.9895E-02 -.6403E-02 -.4017E-14 -.2110E-14  .9895E-02  .6403E-02  .1343E-01  .7116E-02  .9110E-02  .3891E-02
 -.5272E-14 -.1946E-14 -.9116E-02 -.3891E-02 -.1343E-01 -.7116E-02  .5242E-02 -.1527E-02  .5021E-15 -.7826E-15
 -.5242E-02  .1527E-02 -.7254E-02  .2291E-02 -.5026E-02  .1714E-02 -.1255E-15 -.1059E-14  .5026E-02 -.1714E-02
  .7254E-02 -.2291E-02
```

Figure 30. Partial output of BOTZCW for Problem 2c.

```
OLD Y MATRIX PARAMETERS:
                          NMODE    NP      NC     NPR      NE      NW     NPW      NJ
                            4      19       2       5       0       0       0       0

        MODE NO. OF ADDITIONS:         CAPS        WIRES
                                         4           0

NEW ADDITIONS:                                                          } User-specified
                          NC1    NPR1     NE1     NW1     NPW1       NJ1 } input for adding
                           0       0       0       1       13       2   } the loop

WIRES ADDED TO MATRIX

NEW Y MATRIX PARAMETERS:
                          NMODE    NP      NC     NPR      NE      NW     NPW      NJ
                            4      19       2       5       0       1      13       2

        MODE NO. OF ADDITIONS:         CAPS        WIRES
                                         4           5

MINIMUM PROGRAM DIMENSIONS ARE AS FOLLOWS:
     PI          Q          R          S         YI         W1         W2+LOAD&WGHT
   20736       1008       1008        49        1024        144             7
```

Figure 31. Partial output of BOT[illegible]IVA for Prob[illegible] 2c when the loop is added to the capped BOT.

```
NUMBER OF SLOT ANTENNAS =  0


   WIRE VOLTAGE

 WIRE INDEX              VOLTAGE
    6             1.0000    0.0000

NUMBER OF FIXED ANGLES =  4

NUMBER OF ANGLES PER FIXED ANGLE =  37

FIXED ANGLE    CODE      VARIABLE ANGLE RANGE

   90.0          1            0.0 -    180.0
    0.0          1            0.0 -    180.0
  -90.0          1            0.0 -    180.0
   90.0          2          -90.0 -     90.0
THE Y MATRIX CONTAINS THE FOLLOWING ADDITIONS ( 0 IF NOT INCLUDED, OR CORRESPONDING MODE NUMBER IF PRESENT):

         CAPS   4
         WIRES  5

  81 SUBMATRICES READ

TOTAL POWER(DB) =  -38.74
```

Figure 32. Partial output of BOTRA for Problem 2c.

		POWER(DB)	
PHI	THETA	θ	φ
90.0	0.0	-2.32	-148.93
90.0	5.0	-2.18	-148.94
90.0	10.0	-2.08	-148.92
90.0	15.0	-1.99	-148.88
90.0	20.0	-1.90	-148.81
90.0	25.0	-1.81	-148.72
90.0	30.0	-1.70	-148.62
90.0	35.0	-1.56	-148.50
90.0	40.0	-1.37	-148.38
90.0	45.0	-1.11	-148.26
90.0	50.0	-.80	-148.14
90.0	55.0	-.42	-148.03
90.0	60.0	-.00	-147.94
90.0	65.0	.43	-147.88
90.0	70.0	.85	-147.84
90.0	75.0	1.23	-147.82
90.0	80.0	1.54	-147.82
90.0	85.0	1.78	-147.84
90.0	90.0	1.94	-147.86
90.0	95.0	2.03	-147.88
90.0	100.0	2.06	-147.91
90.0	105.0	2.05	-147.93
90.0	110.0	2.01	-147.96
90.0	115.0	1.96	-148.00
90.0	120.0	1.89	-148.05
90.0	125.0	1.82	-148.12
90.0	130.0	1.72	-148.21
90.0	135.0	1.59	-148.31
90.0	140.0	1.40	-148.43
90.0	145.0	1.15	-148.55
90.0	150.0	.83	-148.67
90.0	155.0	.43	-148.78
90.0	160.0	-.03	-148.88
90.0	165.0	-.57	-148.96
90.0	170.0	-1.16	-149.01
90.0	175.0	-1.78	-149.03
90.0	180.0	-2.40	-149.01

Figure 32. Concluded.

2.6.3 Problem 3: Wire and Aperture Antennas on Wing Section

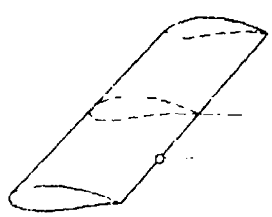
Consider an asymmetric wing section shown in Figure 33a. Two 1/8λ monopoles are mounted on the trailing edge of the wing surface. The monopole at the center of the surface is parasitic. The other is active. The half-length of the wing is 1.38λ.

a) Calculate the principal plane radiation patterns for the foregoing configuration. Calculate the currents on the BOT surface.

b) Compute the electric and magnetic near-fields for the system of radiators at selected points along a line 1/16λ from the wing surface.

c) Calculate the coupling between the two monopoles in this problem. Next assume that there are three aperture antennas (polarized along t) on the wing surface, centered at (t_A, z_A) and (t_B, z_B) and having an axial half-length of L_A and L_B, respectively. Compute the coupling between these slots.

Solution - Figures 33b and 33c list the input data for the three problems. The open BOT system matrix is calculated by executing BOTZSS and BOTINV. The wires are added to the system matrix by executing BOTZSW, BOTZWW, and BOTINVA. The solution to Problems 3a and 3b is obtained by executing BOTRA (see Figure 34a-34c for partial outputs). The solution to Problem 3c is obtained by executing BOTAC (see Figures 35a-35b for partial outputs).



1/8 λ monopole at mid-plane element is parasitic

Figure 33a. Asymmetric wing section - Problem 3.

```
 .2013841E+01
 4 20 14
17
  .2609    .3107    .3235    .3296    .3306    .3263    .3180    .3071    .2805    .2576
  .2485    .2411    .2365    .2363    .2403    .2478    .2609
  .2880    .4830    .6780    .8730   1.0680   1.2630   1.4580   1.6530   1.8480   1.6530
 1.4580   1.2630   1.0680    .8730    .6780    .4830    .2880
 4.3056
 0  0  0
 2 18  2
 1.8482   1.8968   1.9455   1.9943   2.0430   2.0918   2.1405   2.1893   2.2380   1.8480
 1.8968   1.9455   1.9943   2.0430   2.0918   2.1405   2.1893   2.2380
  .2805    .2805    .2805    .2805    .2805    .2805    .2805    .2805    .2805    .2805
  .2805    .2805    .2805    .2805    .2805    .2805    .2805    .2805
  .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000   2.1528
 2.1528   2.1528   2.1528   2.1528   2.1528   2.1528   2.1528   2.1528
       1       10
  .0011    .0011
       1       10
  .1000    .1000
 1.0000   1.0000
  .0000    .0000
  .0000    .0000
0
1
       8
 1.0000    .0000
6 37
    0.0     90.0    180.0    -90.0    90.00    -90.0
      1        1        1        1        2        2
    0.0      0.0      0.0      0.0      0.0      0.0
   180.     180.     180.     180.     180.     180.
3
  .5000    .2805   2.0500
 1.0000    .2805   2.0500   Near-field input data
 1.5000    .2805   2.0500
```

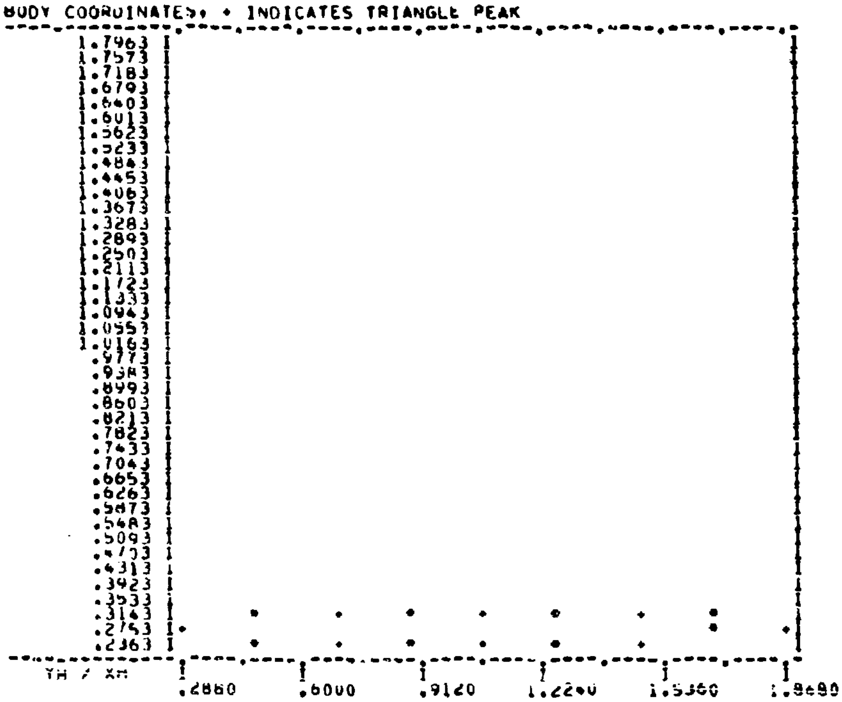
Figure 33b. Input data for execution of Problems 3a and 3b.

```
 .2013841E+01
 4  20  14
17
  .2609    .3107    .3235    .3296    .3306    .3263    .3180    .3071    .2805    .2576
  .2485    .2411    .2365    .2363    .2403    .2478    .2609
  .2880    .4830    .6780    .8730   1.0680   1.2630   1.4580   1.6530   1.8480   1.6530
 1.4580   1.2630   1.0680    .8730    .6780    .4830    .2880
 4.3056
 0   0   0
 2  18   2
 1.8480   1.8968   1.9455   1.9943   2.0430   2.0918   2.1405   2.1893   2.2380   1.8480
 1.8968   1.9455   1.9943   2.0430   2.0918   2.1405   2.1893   2.2380
  .2805    .2805    .2805    .2805    .2805    .2805    .2805    .2805    .2805    .2805
  .2805    .2805    .2805    .2805    .2805    .2805    .2805    .2805
  .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000   2.1528
 2.1528   2.1528   2.1528   2.1528   2.1528   2.1528   2.1528   2.1528
        1       10
  .0011    .0011
        1       10
  .1000    .1000
 1.0000   1.0000
  .0000    .0000
  .0000    .0000
 3
        1        5        6
-3.2293  -3.2293  -3.2293
 3.2293   3.2293   3.2293
 1.0000   0.0000   1.0000   0.0000   1.0000   0.0000   } Slot antenna input data
 1.0000   1.0000   1.0000
 0.0000   0.0000   0.0000
```

Figure 33c. Input data for execution of Problem 3c.

```
    BK
 .20138841E+01
   NMODE     NPT     NBAND     NP
     4        20       14      17

YB
   .2609   .3107   .3235   .3296   .3306   .3263   .3180   .3071   .2805   .2576
   .2485   .2411   .2365   .2363   .2403   .2475   .2609

XB
   .2880   .4830   .6780   .8730  1.0680  1.2630  1.4580  1.6530  1.8480  1.6530
  1.4580  1.2630  1.0680   .8730   .6780   .4830   .2880
```

BODY COORDINATES, + INDICATES TRIANGLE PEAK




```
HALF-LENGTH OF BOT =       4.2056

BOT GENERATING CURVE IS CLOSED.  NP =  19

    NC   NPH   NE
    0     0    0
```

Figure 34a. Partial output of BOTRA for Problem 3a.

NW	NPW	NJ
2	18	2

WIRE COORDINATES

		IW	XW	YW	ZW
WIRE 1 RADW=	.0011	1	1.8480	.2805	0.0000
		2	1.8968	.2805	0.0000
		3	1.9455	.2805	0.0000
		4	1.9943	.2805	0.0000
		5	2.0430	.2805	0.0000
		6	2.0918	.2805	0.0000
		7	2.1405	.2805	0.0000
		8	2.1893	.2805	0.0000
		9	2.2380	.2805	0.0000
WIRE 2 RADW=	.0011	10	1.8480	.2805	2.1528
		11	1.8968	.2805	2.1528
		12	1.9455	.2805	2.1528
		13	1.9943	.2805	2.1528
		14	2.0430	.2805	2.1528
		15	2.0918	.2805	2.1528
		16	2.1405	.2805	2.1528
		17	2.1893	.2805	2.1528
		18	2.2380	.2805	2.1528

JUNCTION PARAMETERS

IJ	RADJ	UXJ	UYJ	UZJ
1	.1000	1.0000	0.0000	0.0000
2	.1000	1.0000	0.0000	0.0000

NUMBER OF SLOT ANTENNAS = 0

WIRE VOLTAGES

WIRE INDEX	VOLTAGE	
8	1.0000	0.0000

NUMBER OF FIXED ANGLES = 6

NUMBER OF ANGLES PER FIXED ANGLE = 37

FIXED ANGLE	CODE	VARIABLE ANGLE RANGE
0.0	1	0.0 - 180.0
90.0	1	0.0 - 180.0
180.0	1	0.0 - 180.0
-90.0	1	0.0 - 180.0
90.0	2	0.0 - 180.0
-90.0	2	0.0 - 180.0

THE Y MATRIX CONTAINS THE FOLLOWING ADDITIONS (0 IF NOT INCLUDED, OR CORRESPONDING MODE NUMBER IF PRESENT):

CAPS 0
WIRES 4

64 SUBMATRICES READ

TOTAL POWER(DB) = -41.84

PHI	THETA	POWER(DB) θ	φ
0.0	0.0	1.71	-41.24
0.0	5.0	2.75	-41.70
0.0	10.0	3.27	-42.60
0.0	15.0	3.34	-44.11
0.0	20.0	2.96	-46.34
0.0	25.0	2.11	[illegible]
0.0	30.0	.75	-54.28
0.0	35.0	-1.10	-51.02
0.0	40.0	-3.20	-47.40
0.0	45.0	-4.82	-45.78
0.0	50.0	-5.25	-46.02
0.0	55.0	-6.77	-48.47
0.0	60.0	[illegible]	[illegible]
0.0	65.0	-6.95	-54.50
0.0	70.0	-6.68	-48.37
0.0	75.0	-9.53	-45.87
0.0	80.0	-11.47	-45.66
0.0	85.0	-11.40	-47.34
0.0	90.0	-12.41	-51.03
0.0	95.0	-15.28	-56.73
0.0	100.0	-17.94	-58.57
0.0	105.0	-9.53	-55.12
0.0	110.0	-6.82	-52.53
0.0	115.0	-4.72	-50.67
0.0	120.0	-3.83	-49.21
0.0	125.0	-3.58	-47.95
0.0	130.0	-3.20	-46.78
0.0	135.0	-1.84	-45.68
0.0	140.0	.15	-44.66
0.0	145.0	1.96	-43.76
0.0	150.0	3.26	-42.98
0.0	155.0	4.04	-42.32
0.0	160.0	4.39	-41.77
0.0	165.0	4.36	-41.33
0.0	170.0	4.01	-40.98
0.0	175.0	3.37	-40.72
0.0	180.0	2.39	-40.58

Figure 34a. Concluded.

NEAR FIELD ANALYSIS

			E-FIELD			H-FIELD		
			FIELD COMPONENTS			FIELD COMPONENTS		
ZTEST	YTEST	XTEST	X	Y	Z	X	Y	Z
.5000	.2805	2.0500	.5502E-01	.2019E-03	.3256E-01	.3870E-06	.9076E-04	.2226E-06
1.0000	.2805	2.0500	.4074E-01	.9852E-04	.1290E+00	.7767E-06	.1921E-03	.2977E-06
1.5000	.2805	2.0500	.5734E-01	.2185E-03	.1626E+00	.7485E-06	.2268E-03	.1673E-06

Figure 34b. Partial output of BOTRA for Problem 3b.

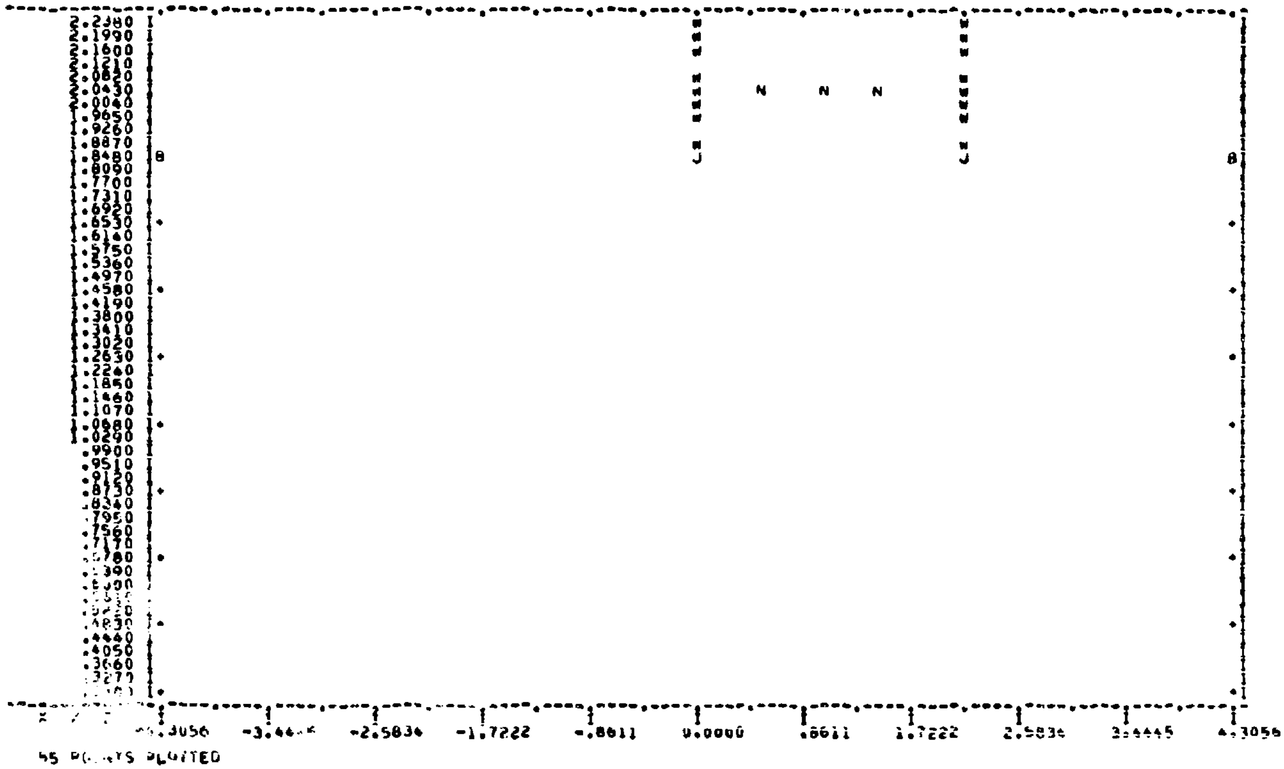
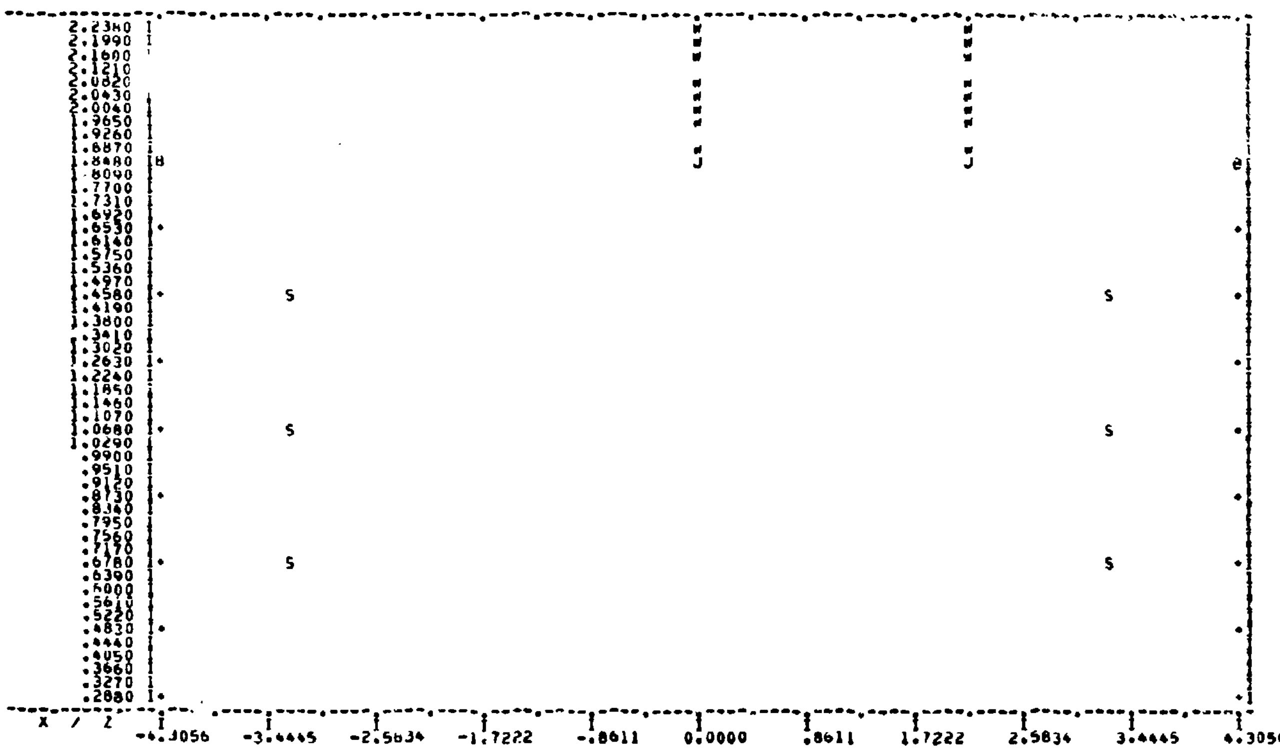


Figure 34c. Partial output of BOTRA for Problems 3a-3b.

```
NUMBER OF SLOT ANTENNAS =  3

ANTENNA NO.   IS    Z0         Z1                  E0               TEXC      ZEXC

      1        1   -3.2293    3.2293    1.0000    0.0000    1.0000    0.0000
      2        5   -3.2293    3.2293    1.0000    0.0000    1.0000    0.0000
      3        6   -3.2293    3.2293    1.0000    0.0000    1.0000    0.0000
THE Y MATRIX CONTAINS THE FOLLOWING ADDITIONS ( 0 IF NOT INCLUDED, OR CORRESPONDING MODE NUMBER IF PRESENT):

        CAPS   0
        WIRES  4

  64 SUBMATRICES READ

SLOT-SLOT ANTENNA COUPLING
  SLOT A    SLOT B    T AND Z COUPLING COEFFS. (COMPLEX)

     1         1      .389E-03  .603E-03  .832E-04 -.285E-02
     2         1      .746E-04 -.397E-02 -.120E-04  .120E-03
     3         1      .821E-04 -.265E-02  .146E-05 -.241E-03
     1         2      .767E-04 -.403E-02 -.356E-05 -.690E-05
     2         2      .372E-03  .192E-02  .541E-04 -.284E-02
     3         2      .446E-03 -.209E-02  .559E-05  .116E-02
     1         3      .823E-04 -.269E-02  .560E-05 -.389E-03
     2         3      .446E-03 -.210E-02  .304E-04  .951E-03
     3         3      .515E-03 -.738E-03  .604E-04 -.232E-02

WIRE-WIRE ANTENNA COUPLING
  JUNC A    JUNC B    COUPLING COEFF. (COMPLEX)

     1         1      .579E-04  .246E-02
     2         1     -.219E-04  .468E-05
     1         2     -.219E-04  .469E-05
     2         2      .655E-04  .244E-02
```

Figure 35a. Partial output of BOTAC for Problem 3c.



58 POINTS PLOTTED

Figure 35b. Partial output of BOTAC for Problem 3c.

2.6.4 Problem 4: Scattering from a Closed Cylinder

Consider a circular closed cylinder of 2.76λ length and 0.216λ radius. (The uncapped cylinder of same dimensions is used in sample Problem 1.)

a) Calculate the monostatic (backscatter) cross section of the body for horizontal (θθ) and vertical (ϕϕ) polarizations as a function of azimuthal (θ) angles.

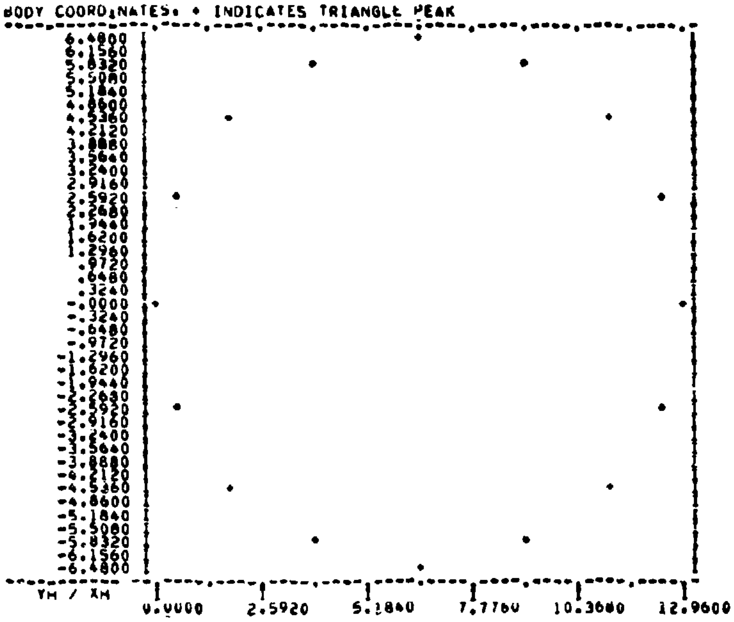
b) Calculate the bistatic cross section of the body for horizontal and vertical polarization as a function of θ. Assume the illumination is normal (i.e., along θ = 90).

Solution - Figure 36 lists the input data for the two problems. The closed BOT system matrix is calculated by executing BOTZSC, BOTZCC, and BOTINVA using the open BOT systems matrix from Problem 1. The solution to Problem 4a is obtained by executing BOTSCM (see Figure 37 for partial output). The solution to Problem 4b is obtained by executing BOTSCB (see Figure 38 for partial output).

```
 .2094397E+00
 4 20 14
17
 0.0000  2.4798  4.5821  5.9867  6.4800  5.9867  4.5821  2.4795  -.0000 -2.4798
-4.5821 -5.9867 -6.4800 -5.9867 -4.5821 -2.4795  0.0000
 0.0000   .4933  1.8979  4.0002  6.4800  8.9595 11.0021 12.4667 12.9600 12.4667
11.0621  8.9598  6.4800  4.0002  1.8979   .4933  0.0000
41.4
 2  5  1
 6.4800  0.0000
41.4000-41.4000                                    Cap data set with edge term included
 0.0000  0.2500  0.5000  0.7500  1.0000
36.4000-36.4000
 0   0   0
 2 46     0.0     90.0
    0.0    90.0
      1       2                Radiation angles and incident angle
    0.0     0.0
   90.0    90.0
 0
```

Figure 36. Input data for execution of Problems 4a-4b.

```
    BK
 .2094397E+00
   NMODE     NPT      NBAND     NP
     4        20        14      17

YB
  0.0000  2.4798  4.5821  5.9867  6.4800  5.9867  4.5821  2.4798  0.0000 -2.4798
 -4.5821 -5.9867 -6.4800 -5.9867 -4.5821 -2.4798  0.0000

XB
  0.0000   .4933  1.8979  4.0002  6.4800  8.9598 11.0621 12.4667 12.9600 12.4667
 11.0621  8.9598  6.4800  4.0002  1.8979   .4933  0.0000

BODY COORDINATES. * INDICATES TRIANGLE PEAK
```



```
HALF-LENGTH OF BOT =      41.4000

BOT GENERATING CURVE IS CLOSED.  NP =  19

BOT GENERATING CURVE HAS UNIFORM SEGMENTATION

   NC  NPR   NE
    2    5    2

 CAP       XC        YC        ZC        ZE

  1       6.4800   0.0000  41.4000  36.4000
  2       6.4800   0.0000 -41.4000 -35.4000

RHOC
 0.0000    .2500    .5000    .7500   1.0000

     NW       NPW       NJ
      0        0         0

NUMBER OF FIXED ANGLES =  2
NUMBER OF ANGLES PER FIXED ANGLE =  46

FIXED ANGLE     CODE      VARIABLE ANGLE RANGE

    0.0           1            0.0 -     90.0
   90.0           2            0.0 -     90.0
THE Y MATRIX CONTAINS THE FOLLOWING ADDITIONS ( 0 IF NOT INCLUDED, OR CORRESPONDING MODE NUMBER IF PRESENT):
          CAPS   4
          WIRES  0

  64 SUBMATRICES READ
```

Figure 37. Partial output of BOTSCM for Problem 4a.

PHI	THETA	MONO-STATIC RCS(DB) θθ	φφ	θφ	φθ
0.0	0.0	.46	.46	-252.39	-253.97
0.0	2.0	.50	.47	-251.16	-253.75
0.0	4.0	.63	.52	-250.33	-254.27
0.0	6.0	.80	.57	-249.82	-254.05
0.0	8.0	.97	.60	-249.27	-254.22
0.0	10.0	1.09	.57	-248.65	-254.44
0.0	12.0	1.08	.43	-247.99	-254.80
0.0	14.0	.89	.12	-247.71	-255.36
0.0	16.0	.43	-.42	-247.07	-255.28
0.0	18.0	-.39	-1.29	-246.79	-255.28
0.0	20.0	-1.68	-2.63	-245.88	-253.79
0.0	22.0	-3.57	-4.63	-245.23	-252.27
0.0	24.0	-6.05	-7.63	-244.54	-250.60
0.0	26.0	-8.22	-11.42	-243.64	-248.94
0.0	28.0	-7.79	-11.20	-243.37	-247.67
0.0	30.0	-5.64	-7.06	-242.96	-246.77
0.0	32.0	-3.91	-3.80	-243.19	-246.43
0.0	34.0	-3.14	-1.65	-243.72	-246.57
0.0	36.0	-3.45	-.38	-245.27	-247.14
0.0	38.0	-5.06	.14	-247.27	-248.69
0.0	40.0	-8.52	-.10	-250.74	-251.15
0.0	42.0	-13.30	-1.24	-256.25	-254.04
0.0	44.0	-9.84	-3.61	-260.62	-254.75
0.0	46.0	-5.40	-8.12	-256.08	-253.59
0.0	48.0	-3.16	-15.50	-251.95	-252.52
0.0	50.0	-2.56	-9.84	-250.90	-251.93
0.0	52.0	-3.50	-5.06	-250.08	-253.73
0.0	54.0	-6.28	-3.02	-250.23	-259.55
0.0	56.0	-12.24	-2.82	-250.28	-279.35
0.0	58.0	-23.42	-4.46	-250.03	-258.78
0.0	60.0	-14.68	-8.90	-250.00	-253.00
0.0	62.0	-13.22	-20.42	-251.63	-251.56
0.0	64.0	-18.92	-11.58	-254.35	-252.10
0.0	66.0	-15.45	-2.88	-261.10	-255.21
0.0	68.0	-6.37	-6.01	-281.35	-262.41
0.0	70.0	-2.12	-7.55	-260.00	-272.32
0.0	72.0	-.17	-8.11	-255.40	-262.22
0.0	74.0	-.03	-4.60	-253.65	-266.85
0.0	76.0	-2.08	-2.00	-252.61	-276.48
0.0	78.0	-8.88	-1.71	-251.47	-256.96
0.0	80.0	-11.59	-3.99	-250.46	-249.79
0.0	82.0	-.35	-4.58	-249.22	-247.63
0.0	84.0	4.40	1.24	-249.95	-245.40
0.0	86.0	7.05	5.43	-250.53	-246.33
0.0	88.0	8.46	7.69	-253.73	-249.20
0.0	90.0	8.91	8.39	-257.68	-265.62

64 SUBMATRICES READ

Figure 37. Concluded.

BI-STATIC RCS(DB). INCIDENT PHI = 0.0 THETA = 90.0

PHI	THETA	θθ	φθ	θφ	φφ
0.0	0.0	-2.50	-10.25	-271.37	-241.00
0.0	2.0	-2.32	-10.33	-269.21	-241.13
0.0	4.0	-2.12	-10.37	-267.58	-241.26
0.0	6.0	-1.94	-10.35	-266.27	-241.41
0.0	8.0	-1.79	-10.26	-265.39	-241.52
0.0	10.0	-1.69	-10.07	-264.61	-241.55
0.0	12.0	-1.66	-9.76	-263.83	-241.43
0.0	14.0	-1.71	-9.33	-263.26	-241.10
0.0	16.0	-1.87	-8.78	-262.48	-240.57
0.0	18.0	-2.15	-8.14	-262.46	-239.83
0.0	20.0	-2.59	-7.44	-261.94	-239.01
0.0	22.0	-3.21	-6.72	-261.61	-238.14
0.0	24.0	-4.07	-6.02	-261.45	-237.33
0.0	26.0	-5.26	-5.36	-261.15	-236.56
0.0	28.0	-6.88	-4.82	-260.98	-235.96
0.0	30.0	-9.18	-4.36	-260.97	-235.50
0.0	32.0	-12.55	-4.04	-260.96	-235.20
0.0	34.0	-17.32	-3.86	-260.99	-235.11
0.0	36.0	-17.71	-3.85	-261.58	-235.24
0.0	38.0	-12.63	-4.04	-261.80	-235.60
0.0	40.0	-8.66	-4.49	-262.46	-236.28
0.0	42.0	-6.27	-5.10	-263.07	-237.28
0.0	44.0	-4.46	-5.98	-263.95	-238.73
0.0	46.0	-3.19	-7.02	-264.83	-240.70
0.0	48.0	-2.38	-8.00	-265.36	-243.05
0.0	50.0	-1.97	-8.44	-266.03	-245.18
0.0	52.0	-1.95	-7.99	-266.57	-245.28
0.0	54.0	-2.38	-6.88	-266.17	-243.56
0.0	56.0	-3.32	-5.64	-266.44	-241.74
0.0	58.0	-4.98	-4.62	-266.53	-240.47
0.0	60.0	-7.79	-3.98	-267.58	-239.82
0.0	62.0	-13.06	-3.81	-268.46	-239.80
0.0	64.0	-20.21	-4.17	-270.71	-240.42
0.0	66.0	-10.64	-5.11	-273.55	-241.77
0.0	68.0	-5.06	-6.52	-278.03	-243.94
0.0	70.0	-1.51	-7.40	-278.94	-247.19
0.0	72.0	1.05	-5.89	-275.72	-250.27
0.0	74.0	3.02	-2.81	-273.41	-249.26
0.0	76.0	4.58	.15	-274.13	-246.39
0.0	78.0	5.82	2.57	-272.98	-244.38
0.0	80.0	6.81	4.46	-272.21	-243.53
0.0	82.0	7.59	5.96	-268.55	-243.59
0.0	84.0	8.17	7.05	-264.93	-244.68
0.0	86.0	8.58	7.80	-261.77	-247.03
0.0	88.0	8.83	8.25	-259.25	-251.68
0.0	90.0	8.91	8.39	-257.66	-265.67

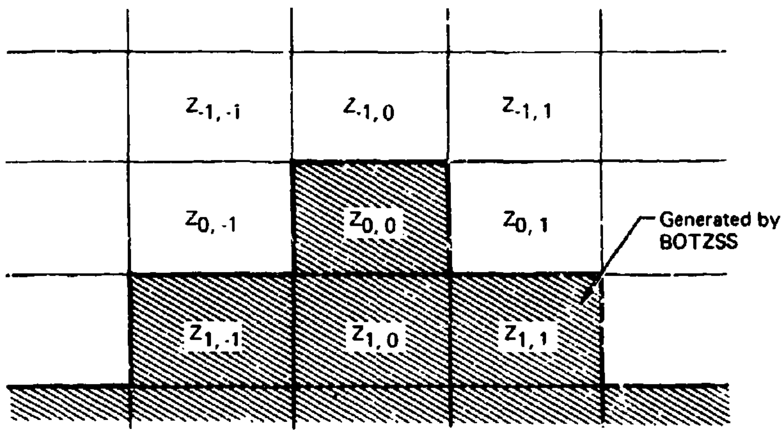
Figure 38. Partial output of BOTSCB for Problem 4b.

3. SYSTEMS SECTION: DETAILED PROGRAM DESCRIPTIONS

A detailed description of each A-STAR program (Figure 1) is given below, including a description of the flow diagram, subroutine input/output arguments, and the special matrix properties used. A description of the common variables used in the program, along with storage methods used in certain arrays, is given in Appendix A. A description of subroutines is given in Section 3.6.

3.1 BOTZSS Program

BOTZSS generates the impedance submatrices $Z^{ss}_{m,n}$ for modes m,n where $0 \leq m \leq NMODE - 1$, $-m \leq n \leq +m$, and $|m - n| < NBAND$. The impedance matrices are generated in the lower triangular portion of Z_{BOT} (Figure 39). Symmetry conditions are then applied in BOTINV to fill the entire Z_{BOT} matrix. The structure of the Z_{BOT} matrix is as follows:



where each of the $Z^{ss}_{m,n}$ matrices is comprised of four submatrices as follows:

$$\left[\begin{array}{c|c} Z^{sstt}_{m,n} & Z^{sstz}_{m,n} \\ \hline Z^{sszt}_{m,n} & Z^{sszz}_{m,n} \end{array}\right].$$

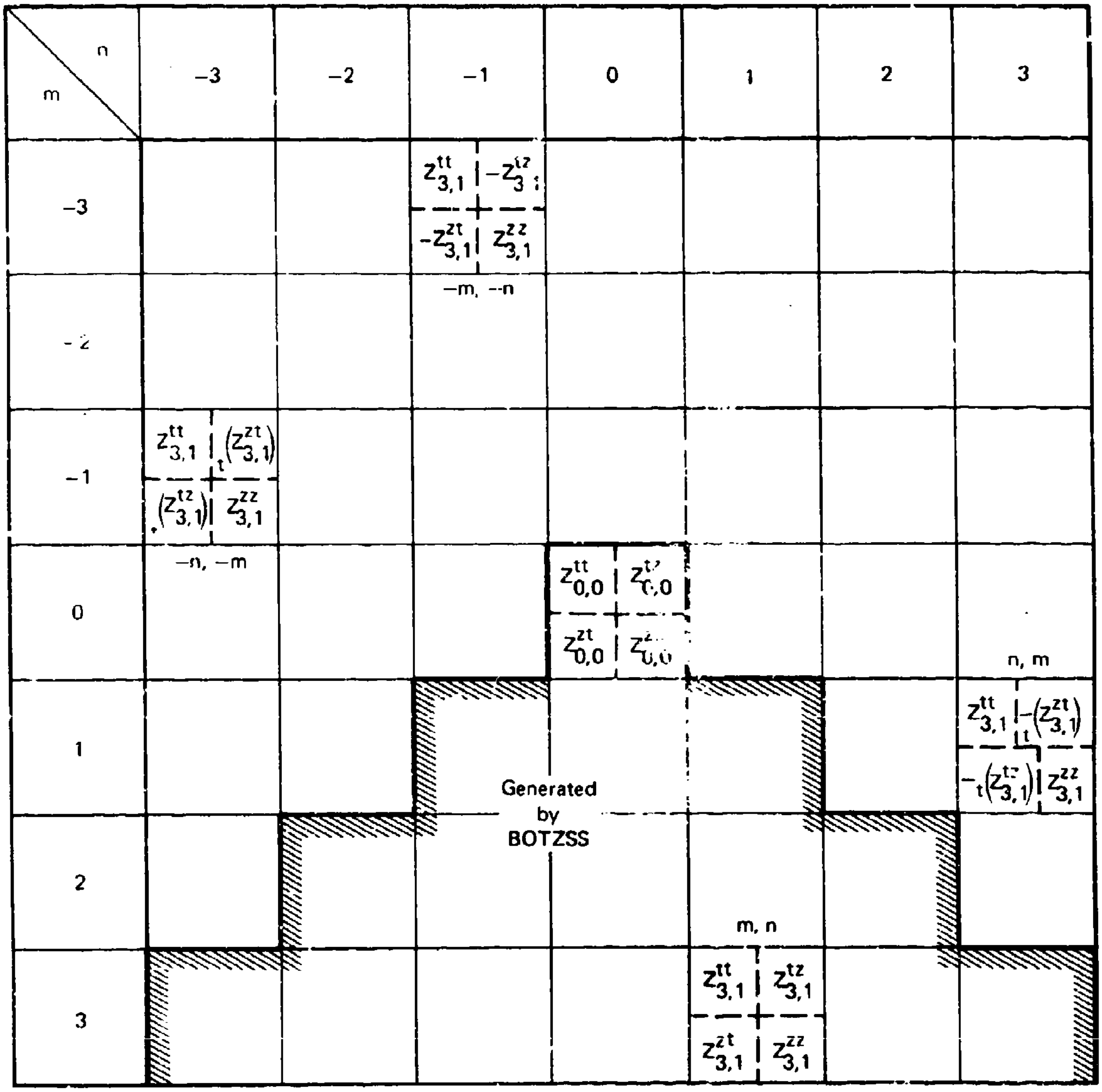


Figure 39. Z_{BOT} matrix symmetries.

Figure 40 shows the flow diagram for BOTZSS. The equation numbers refer to the analytical expressions in Volume I of this report.

The computation of the Green's function kernel takes advantage of the fact that $G_{m,n}$ is symmetric (i.e., $G_{m,n} = {}_tG_{m,n}$), where t indicates the transpose operation. Only the upper triangular portion is stored, as indicated in the appendix; hence $(G_{m,n})_{i,j}$ is stored in location

G(i + (j-1)j/2) when i < j

and

G(j + (i-1)i/2) when i > j.

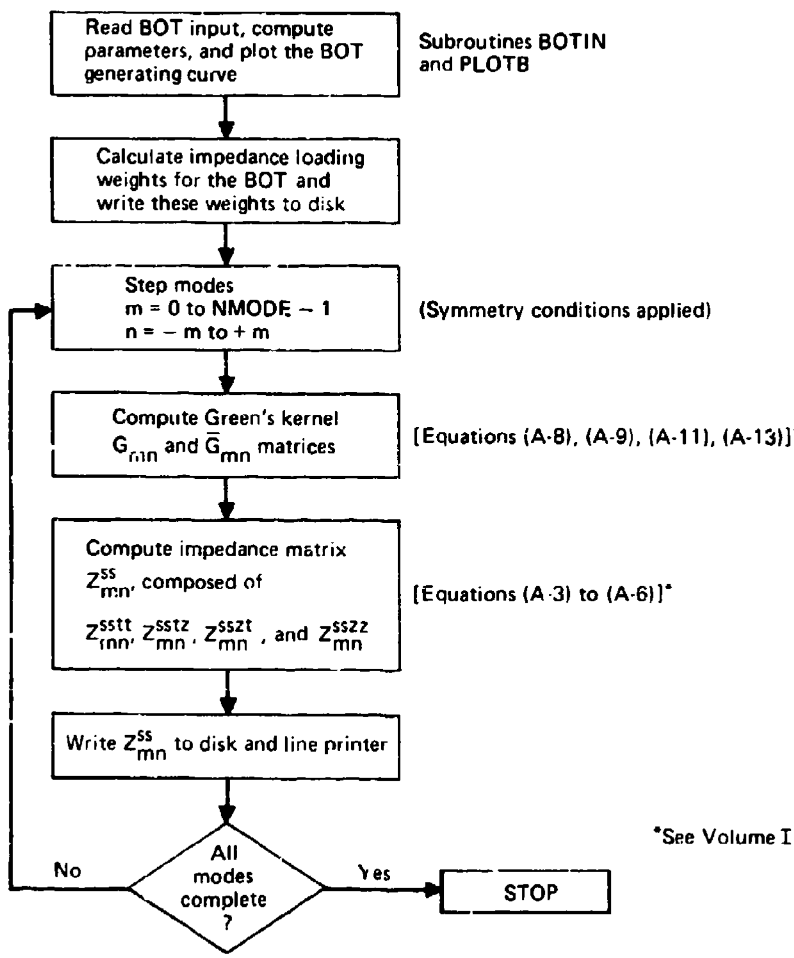


Figure 40. BOTZSS flow diagram.

The section that computes the impedance matrix $Z^{ss}_{m,n}$ uses the following symmetries:

$$Z^{sstt}_{m,n} = {}_t(Z^{sstt}_{m,n}),$$

$$m_t(Z^{sstz}_{m,n}) = -n\,(Z^{sszt}_{m,n}),$$

and

$$Z^{sszz}_{m,n} = {}_t(Z^{sszz}_{m,n}).$$

Thus only the upper triangular portion of each of the $Z^{sstt}_{m,n}$, $Z^{sszt}_{m,n}$, $Z^{sstz}_{m,n}$, and $Z^{sszz}_{m,n}$ needs to be computed. The remaining portion is filled using the symmetry conditions above.

Since the z-directed currents on the BOT are expanded as $\epsilon^{jn\pi z/L} - (-1)^n$, the n=0 mode should not be included. However, in order to maintain a parallel treatment for the t- and z-directed BOT currents, the n=0 (z-directed) mode is included, yielding

$$Z^{sstz}_{mo} = Z^{sszt}_{on} = Z^{sszz}_{mo} = Z^{sszz}_{on} = 0.$$

This addition leads to a singular impedance matrix since the n=0 mode z-directed BOT current coefficients are arbitrary. To circumvent this predicament, the BOTZSS program sets $Z^{sszz}_{oo} = I$, where I is the identity matrix, and the matrix inversion can be performed without alteration, which is equivalent to forcing the n=0 (z-directed) mode BOT current coefficients to be zero.

3.2 BOTINV Program

BOTINV fills the Z_{BOT} matrix using the output file from BOTZSS and inverts this matrix according to the user's specifications. The following symmetries are used to fill Z_{BOT} from the partial Z_{BOT} matrix generated by BOTZSS (see Figure 39 for NMODE = 4):

Main diagonal symmetry (Compute $Z^{ss}_{n,m}$ from $Z^{ss}_{m,n}$)

$$Z^{ss}_{n,m} = \left[\begin{array}{c|c} Z^{sstt}_{n,m} & Z^{sstz}_{n,m} \\ \hline Z^{sszt}_{n,m} & Z^{sszz}_{n,m} \end{array}\right] = \left[\begin{array}{c|c} Z^{sstt}_{m,n} & -{}_t(Z^{sszt}_{m,n}) \\ \hline -{}_t(Z^{sstz}_{m,n}) & Z^{sszz}_{m,n} \end{array}\right]$$

Skew symmetry (Compute $Z_{-n,-m}$ from $Z_{m,n}$)

$$Z^{ss}_{-n,-m} = \left[\begin{array}{c|c} Z^{sstt}_{-n,-m} & Z^{sstz}_{-n,-m} \\ \hline Z^{sszt}_{-n,-m} & Z^{sszz}_{-n,-m} \end{array}\right] = \left[\begin{array}{c|c} Z^{sstt}_{m,n} & {}_t(Z^{sszt}_{m,n}) \\ \hline {}_t(Z^{sstz}_{m,n}) & Z^{sszz}_{m,n} \end{array}\right]$$

Figure 41 shows the flow diagram for BOTINV. Three types of matrix inversions are allowed in BOTINV: total inversion, main diagonal inversion, and partial inversion. Each of these options is described next.

Total Inversion - Total inversion is performed when NBAND > 2*NMODE-1. In this case, the Z_{BOT} matrix is stored by columns as follows:

$(Z^{sstt}_{m,n})_{ij}$: Z((n + NMODE-1)*LS^2*(2*NMODE-1)

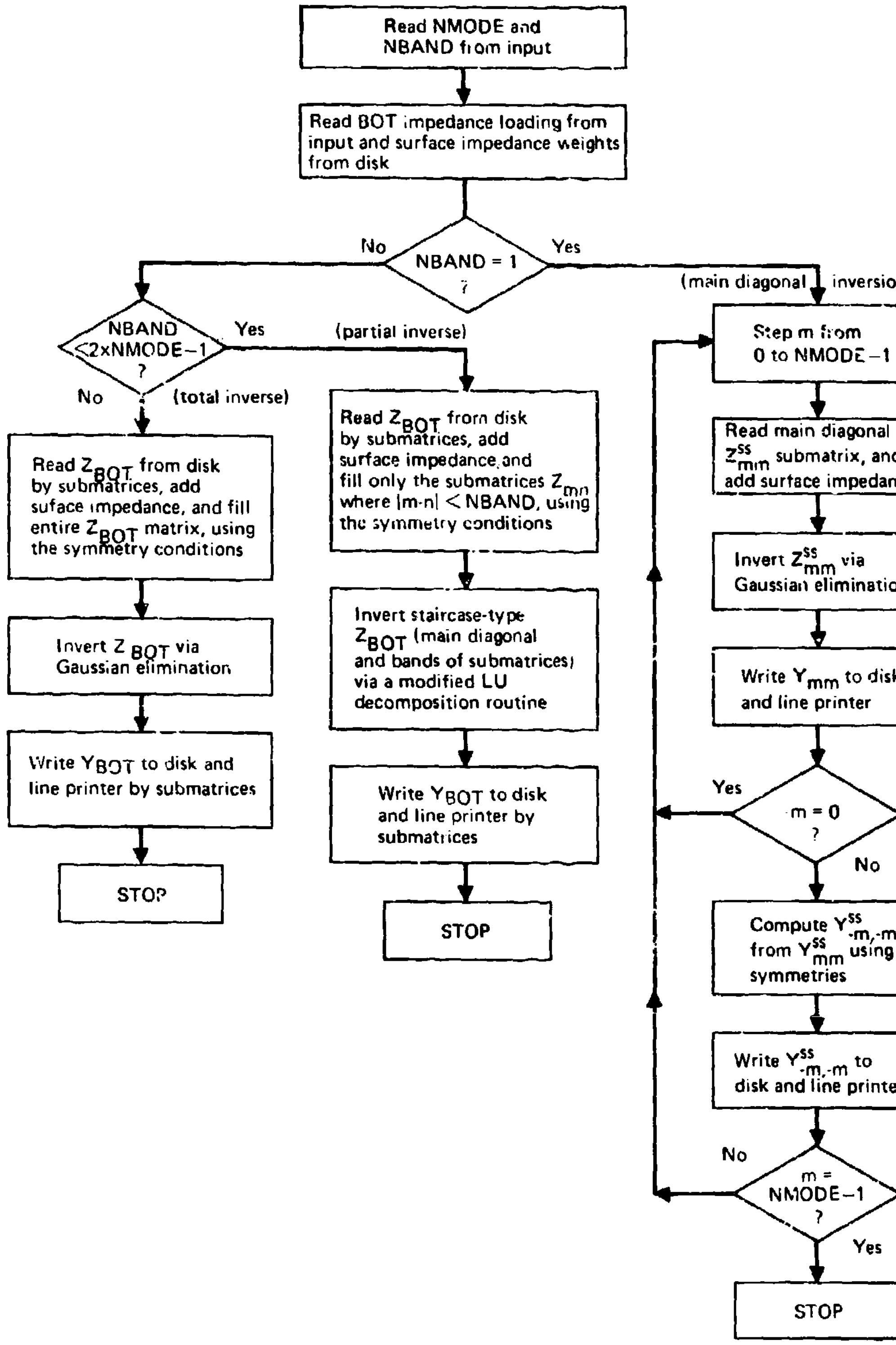


Figure 41. BOTINV flow diagram.

$+ (j-1)*(2*NMODE-1)*LS$

$+ (m + NMODE-1)*LS + i)$

$(Z^{sszt}_{m,n})_{ij}$ is stored at $(Z^{sstt}_{m,n})_{ij}$ + NM

$(Z^{sstz}_{m,n})_{ij}$ is stored at $(Z^{sstt}_{m,n})_{ij}$ + NM*LS*(2*NMODE-1)

$(Z^{sszz}_{m,n})_{ij}$ is stored at $(Z^{sstz}_{m,n})_{ij}$ + NM

Once the Z_{BOT} matrix is filled, it is inverted using Gaussian elimination with partial pivoting, and written to disk file by submatrices.

Main Diagonal Inversion - Main diagonal inversion is performed when NBAND = 1. In this case, the individual diagonal submatrices are inverted separately using Gaussian elimination. For m ≠ 0, the following symmetry is used:

$$Z^{ss}_{-m,-m} = \left[\begin{array}{c|c} Z^{sstt}_{-m,-m} & Z^{sstz}_{-m,-m} \\ \hline Z^{sszt}_{-m,-m} & Z^{sszz}_{-m,-m} \end{array}\right] = \left[\begin{array}{c|c} Z^{sstt}_{m,m} & -Z^{sstz}_{m,m} \\ \hline -Z^{sszt}_{m,m} & Z^{sszz}_{m,m} \end{array}\right]$$

which implies that

$$(Z^{ss}_{-m,-m})^{-1} = Y^{ss}_{-m,-m}$$

has the same symmetries. Thus only $Z^{ss}_{m,m}$ is inverted where m = 0 to NMODE-1. The symmetries are used, and the resulting (2*NMODE-1) submatrices are written to disk file.

Partial Inversion - Partial inversion is performed when NBAND<2*NMODE-1, and NBAND≠1. In this case, the Z_{BOT} matrix is filled only with the $Z^{ss}_{m,n}$ submatrices for which $|m-n| < NBAND$. The resulting Z_{BOT} matrix has a staircase-type structure. The rest of the matrix is sparse. If each of the $Z^{ss}_{m,n}$ submatrices is thought of as an individual element, Z_{BOT} can be considered as a banded matrix. A modified LU (lower-upper triangular) decomposition can then be used with all arithmetic operations replaced by the corresponding matrix operations. The result is an L and U matrix which is also of a staircase-type, but is lower and upper triangular, respectively, when the submatrices are considered as individual elements. The inverse of Z_{BOT} can be computed using forward and backward substitution, again replacing arithmetic operations with matrix operations. The result is a full inverted Z_{BOT} matrix which is written to disk file by submatrices.

The Z_{BOT} matrix is stored by columns, if the individual submatrices $Z^{ss}_{m,n}$ are considered as elements. Only the banded portion is stored. When NMODE = 4 and NBAND = 2 (refer to Figure 41), Z_{BOT} is stored in the following order:

$$Z^{ss}_{-3,-3},\ Z^{ss}_{-2,-3},\ Z^{ss}_{-3,-2},\ Z^{ss}_{-2,-2},\ Z^{ss}_{-1,-2},\ Z^{ss}_{-2,-1}.\ .\ .$$

Each submatrix is stored in LS^2 successive locations by columns. For the example above, $Z^{ss}_{-2,-3}$ would start at index $LS^2 + 1$.

3.3 Description of Impedance Generating Programs

3.3.1 BOTZSW Program

BOTZSW generates the BOT-wire/junction impedance submatrices in Figure 42 for $-NMODE+1 \leq m \leq NMODE-1$. Each of the Z^{sw}_m matrices is comprised of up to four submatrices as follows:

$$\left[\begin{array}{c|c} Z^{sw,t}_m & Z^{sj,t}_m \\ \hline Z^{sw,z}_m & Z^{sj,z}_m \end{array}\right],$$

where t and z correspond to the t- and z-directed current expansions on the

BOT, respectively, and w and j correspond to the wire and junction current expansions, respectively. Figure 43 shows the flow diagram for BOTZSW.

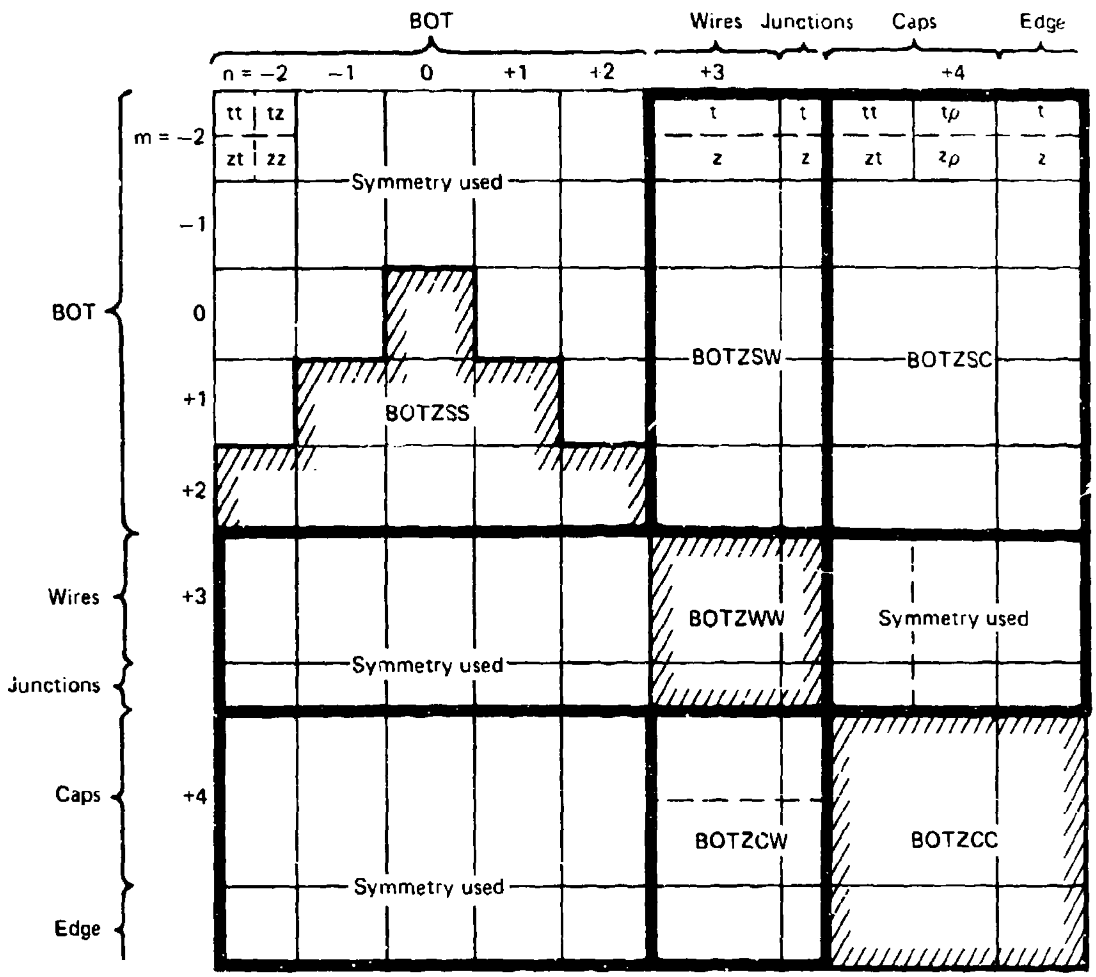


Figure 42. System matrix structure, with wires and caps, when the wires are added first.

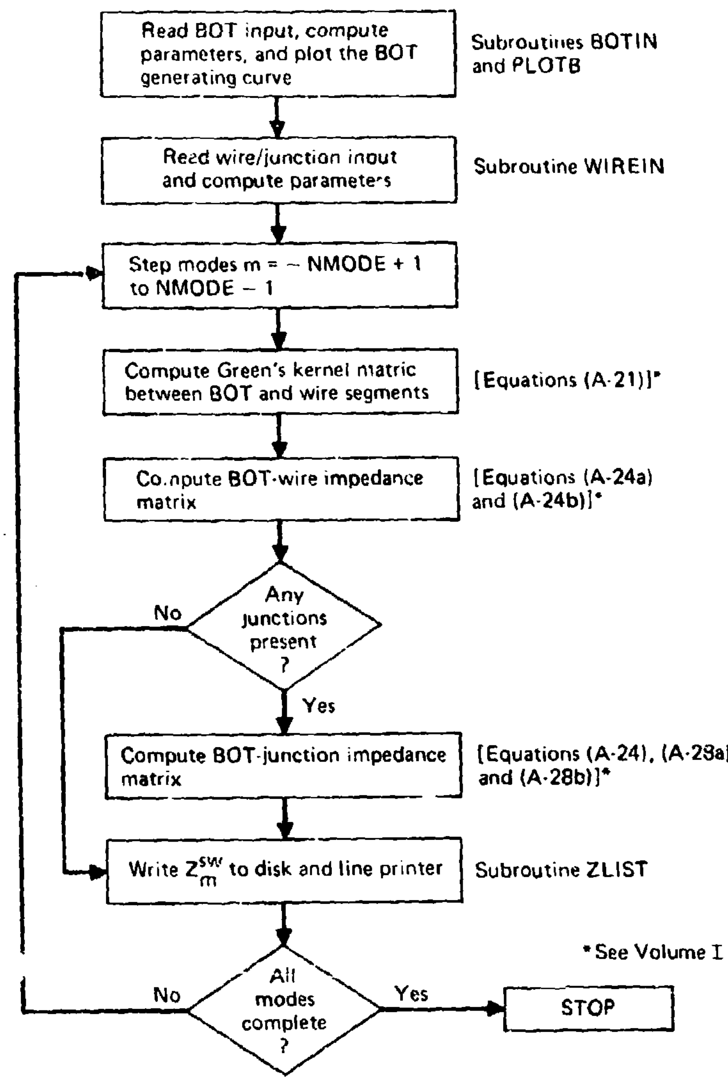


Figure 43 BOTZSW flow diagram.

3.3.2 BOTZWW Program

BOTZWW generates the wire/junction-wire/junction impedance submatrix Z, which is comprised of up to four submatrices as follows:

$$\left[\begin{array}{c|c} Z^{ww} & Z^{wj} \\ \hline Z^{jw} & Z^{jj} \end{array}\right] ,$$

where w and j represent the wire and junction expansions, respectively. BOTZWW uses the symmetry relation $Z^{jw} = {}_tZ^{wj}$, where t indicates the transpose operation. Figure 44 shows the flow diagram for BOTZWW.

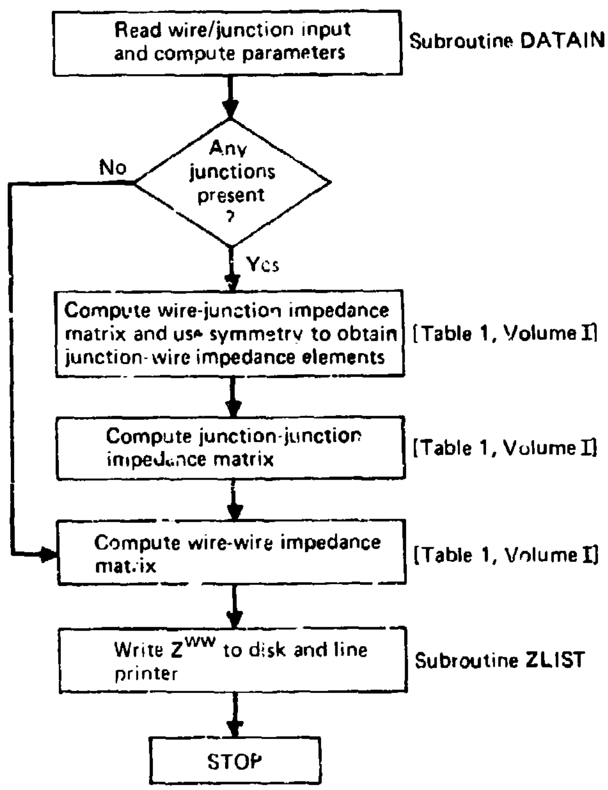


Figure 44. BOTZWW flow diagram.

3.3.3 BOTZSC Program

BOTZSC generates the BOT-cap/edge impedance submatrices Z_m^{sc} for $-NMODE+1 \leq m \leq NMODE-1$. Each of the Z_m matrices is comprised of up to six submatrices as follows:

$$\left[\begin{array}{c|c|c} Z_m^{sc,tt} & Z_m^{sc,t\rho} & Z_m^{sc,te} \\ \hline Z_m^{sc,zt} & Z_m^{sc,z\rho} & Z_m^{sc,ze} \end{array}\right],$$

where the third superscript t or z refers to the t- or z-directed expansions on the BOT, respectively; the fourth superscript refers to the t or ρ expansions on the cap, and e refers to the edge expansions. Figure 45 shows the flow diagram for BOTZSC.

3.3.4 BOTZCC Program

BOTZCC generates the cap/edge-cap/edge impedance submatrix Z^{cc}, which is comprised of up to nine submatrices as follows:

$$\left[\begin{array}{c|c|c} Z^{cc,tt} & Z^{cc,t\rho} & Z^{cc,te} \\ \hline Z^{cc,\rho t} & Z^{cc,\rho\rho} & Z^{cc,\rho e} \\ \hline Z^{cc,et} & Z^{cc,e\rho} & Z^{cc,ee} \end{array}\right],$$

where the t, ρ, and e represent t, ρ cap, and edge expansions, respectively. BOTZCC uses the symmetry relations $Z^{cc,et} = {}_tZ^{cc,te}$ and $Z^{cc,e\rho} = {}_tZ^{cc,\rho e}$, where t indicates the transpose operation. Figure 46 shows the flow diagram for BOTZCC.

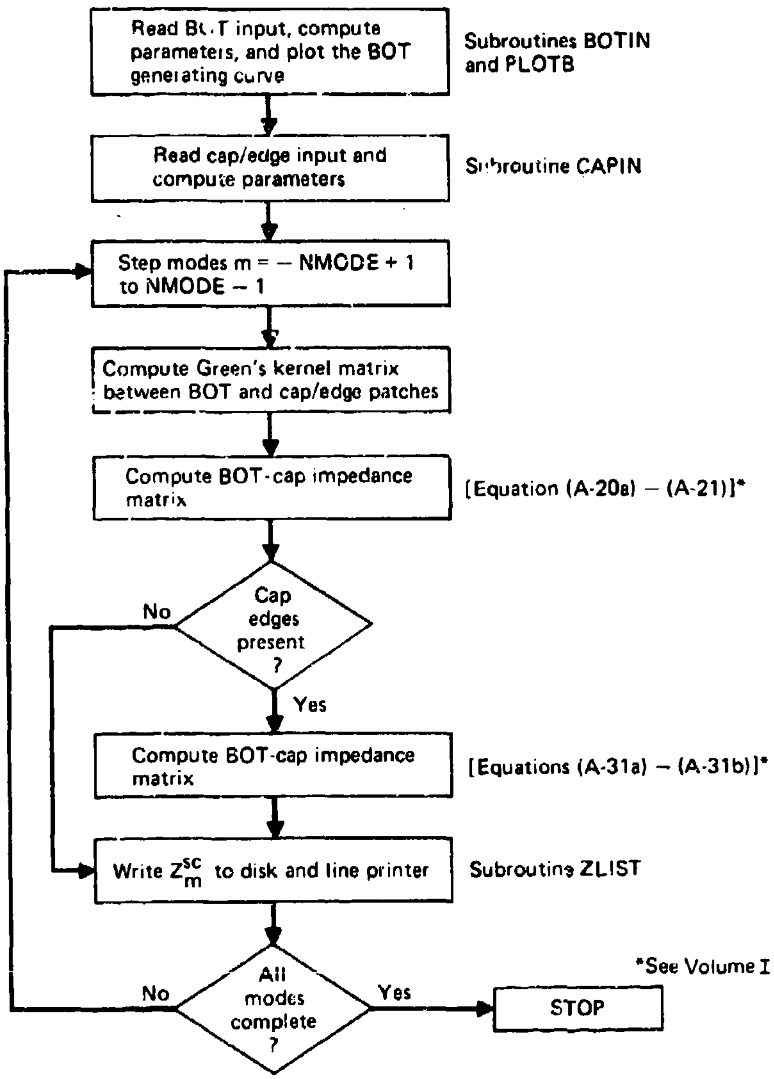


Figure 45. BOTZSC flow diagram.

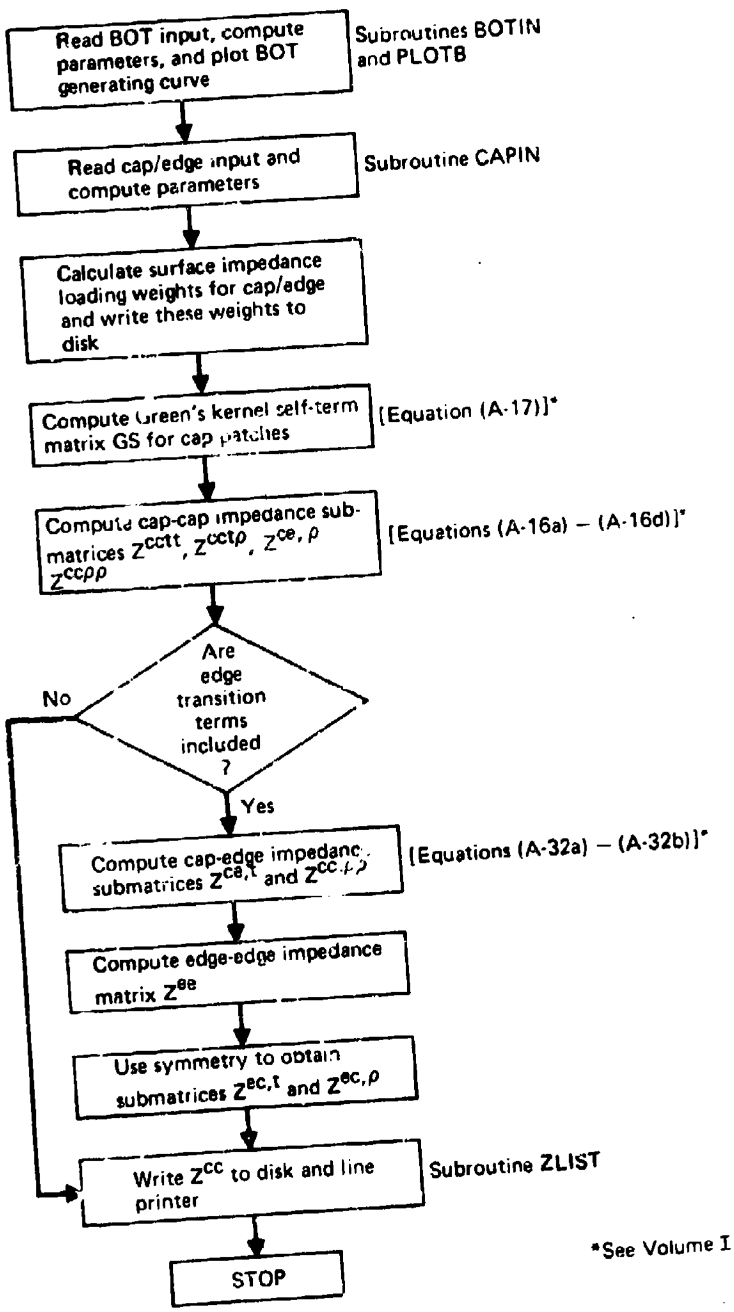


Figure 46. BOTZCC flow diagram.

3.3.5 BOTZCW Program

BOTZCW generates the cap/edge-wire/junction impedance submatrix Z, which is comprised of up to six submatrices as follows:

$$\left[\begin{array}{c|c} Z^{cw,t} & Z^{cj,t} \\ \hline Z^{cw,\rho} & Z^{cj,\rho} \\ \hline Z^{ew} & Z^{ej} \end{array}\right] ,$$

where t, ρ, and e refer to the t, ρ cap, and edge expansions, respectively, and w and j refer to the wire and junction expansions, respectively. The interaction between the cap/edge currents and the junction currents is set to zero (i.e., $Z^{cj,t} = Z^{cj,\rho} = Z^{ej} = 0$). Figure 47 shows the flow diagram for BOTZCW.

3.4 BOTINVA Program

BOTINVA inverts the system matrix when either wires or caps are added to a BOT using a previously inverted system matrix. The new system matrix to be inverted can be written in partitioned form as:

$$\left[\begin{array}{c|c} P & Q \\ \hline R & S \end{array}\right] ,$$

where P is the old system matrix for which P^{-1} already exists on disk, and where Q, R, and S are impedance matrices arising from the addition of wires and/or caps. The inverse of this system is of the form:

$$\left[\begin{array}{c|c} K & L \\ \hline M & N \end{array}\right] ,$$

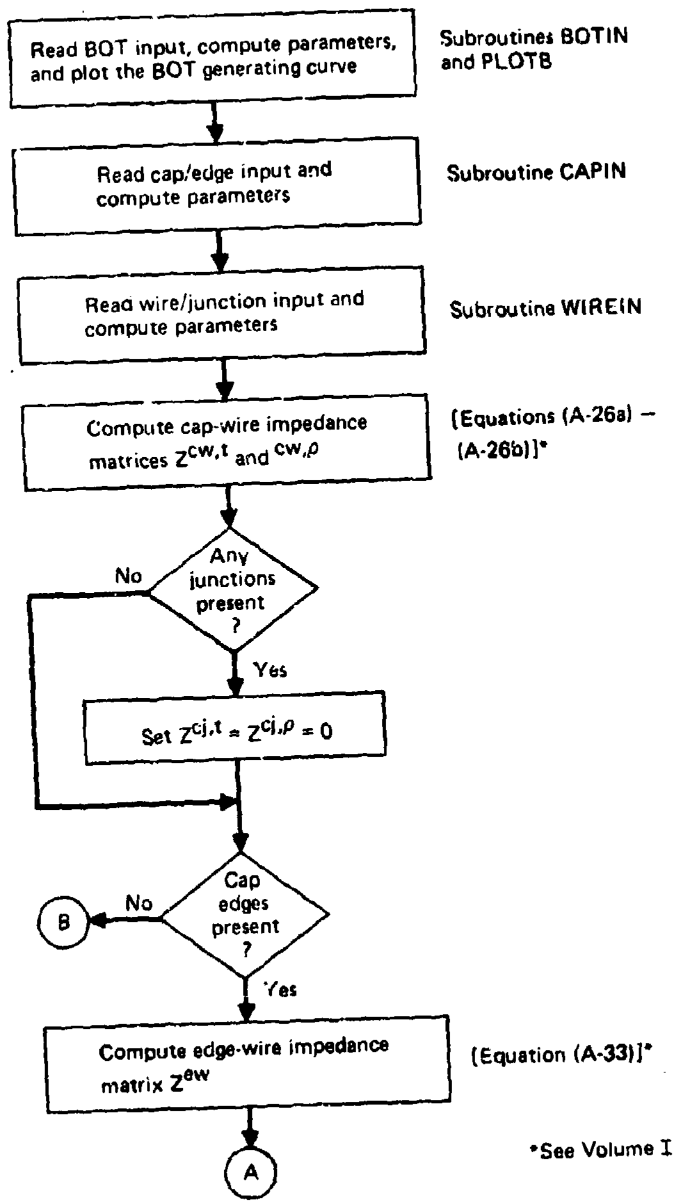


Figure 47. BOTZCW flow diagram.

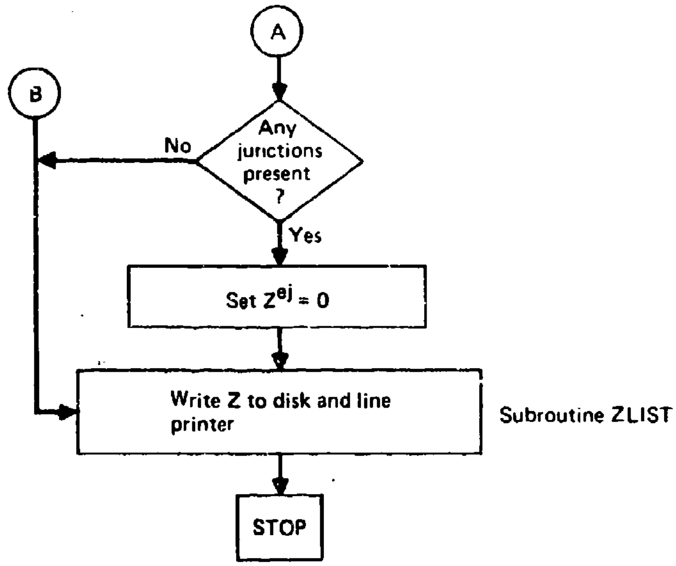


Figure 47. Concluded.

where

$$N = (S-RP^{-1}Q)^{-1}$$
$$L = -P^{-1}QN$$
$$M = -NRP^{-1}$$
$$K = P^{-1}(I-QM).$$

Since P^{-1} already exists, the new inverse can be found by matrix multiplication and by calculating the inverse of a matrix having the same order as S. Figure 39 shows the system matrix that is obtained when caps are added to an old system matrix containing an open BOT with wires and junctions. The S matrix corresponds to the impedance matrix generated by BOTZCC for this case. The same system could be generated by adding the caps first, which would result in a rearrangement of the matrices. In either case, BOTINVA arranges the matrices properly. Figure 48 shows the flow diagram for BOTINVA.

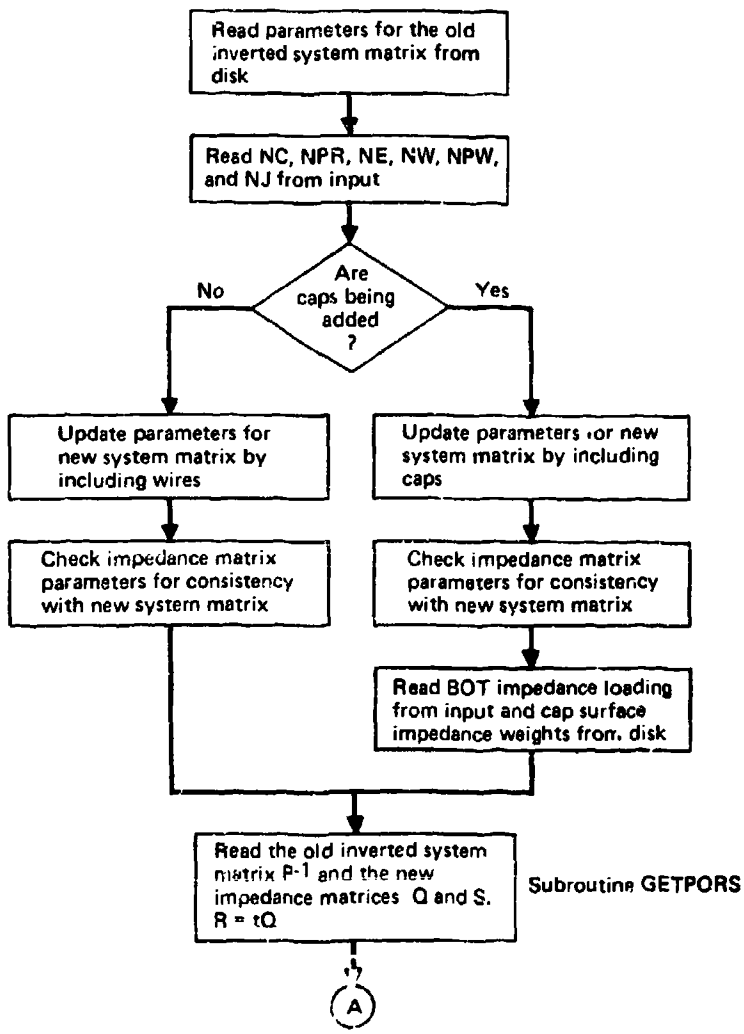


Figure 48. BOTINVA flow diagram.

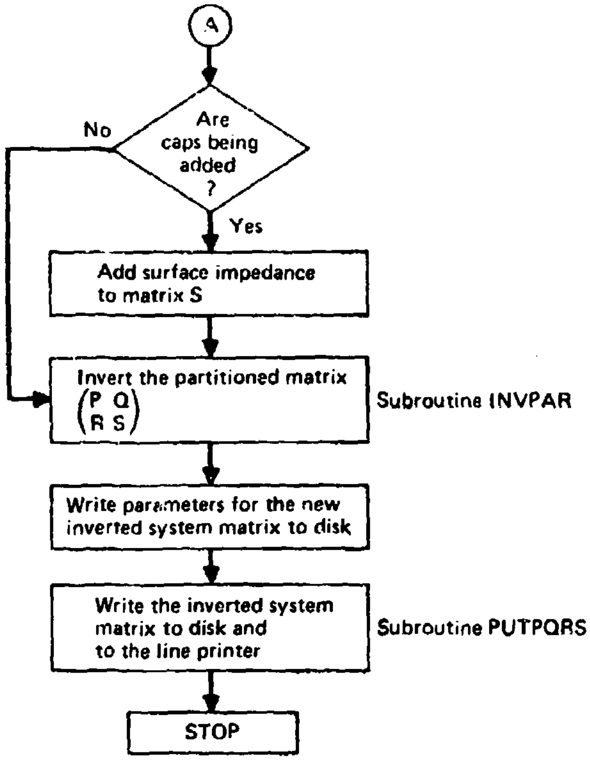


Figure 48. Concluded.

3.5 Radiation/Scattering Analysis Programs

BOTRA Program - BOTRA computes the radiated far and near fields resulting from slot and/or wire antennas on the BOT with or without end-caps present (Sections 5 and 6, Volume I). The presence of wires or caps in the inverted system matrix file is indicated by assigning pseudo mode numbers to the wire and cap blocks in the matrix (see Figure 39). Figure 49 shows the flow diagram for BOTRA.

BOTSCB Program - BOTSCB computes scattered far and near fields in the bistatic mode, with or without wires and end-caps present (Section 5.3, Volume I). Figure 50 shows the flow diagram for BOTSCB.

BOTSCM Program - BOTSCM computes scattered far fields in the monostatic mode (Section 5.3, Volume I). Figure 51 shows the flow diagram for BOTSCM.

BOTAC Program -BOTAC computes the antenna coupling between slot and wire antennas located on th BOT surface (Section 6.3, Volume I). Figure 52 shr the flow diagram for BOTAC.

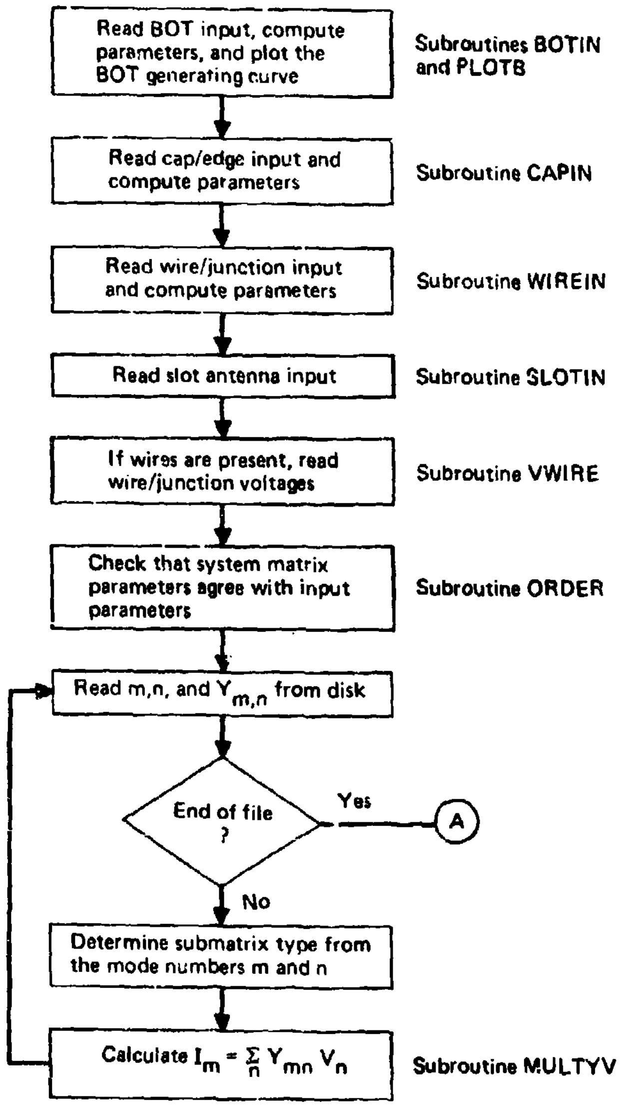


Figure 49. BOTRA flow diagram.

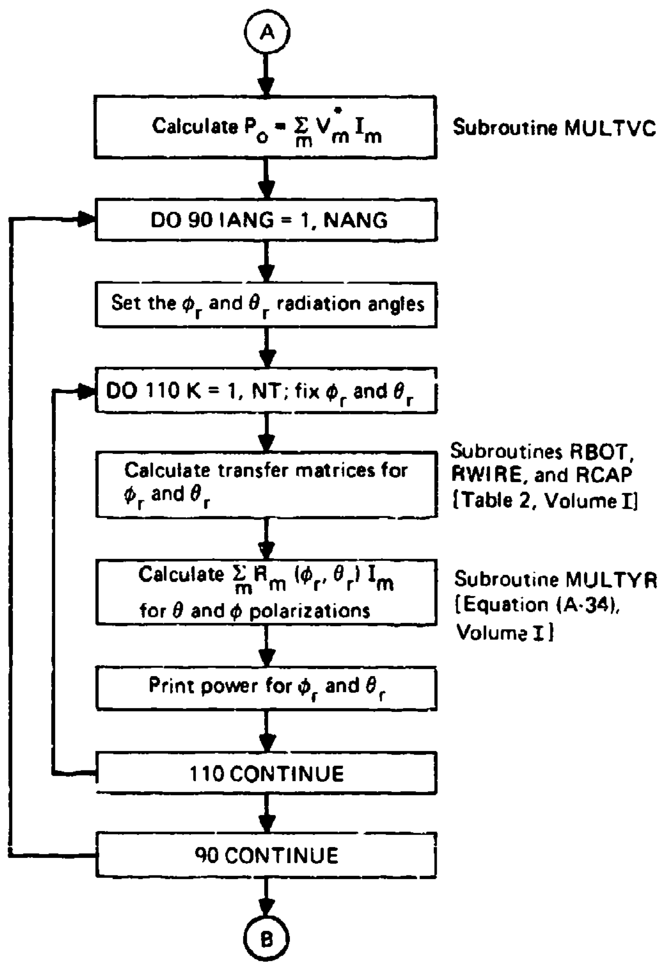


Figure 49. Continued.

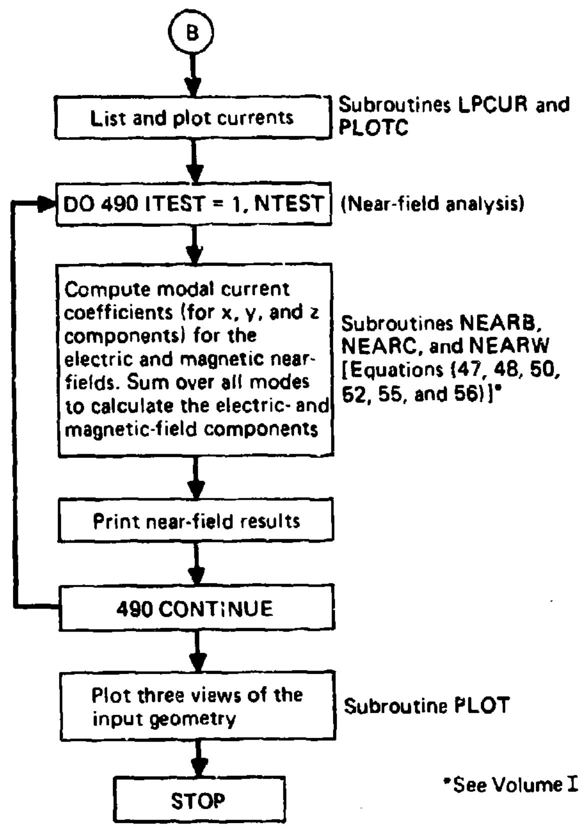


Figure 49. Concluded.

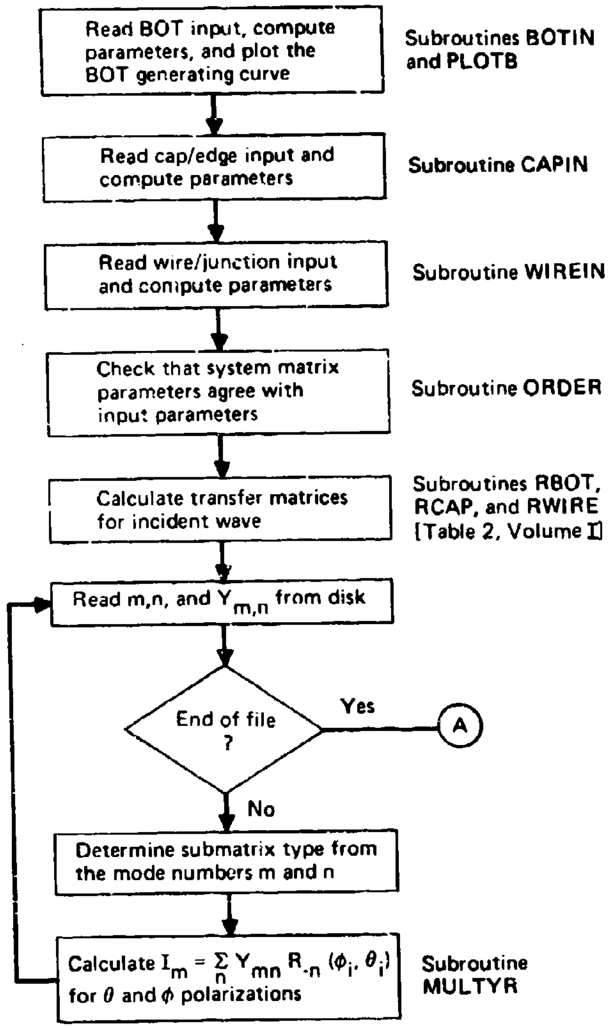


Figure 50. BOTSCB flow diagram.

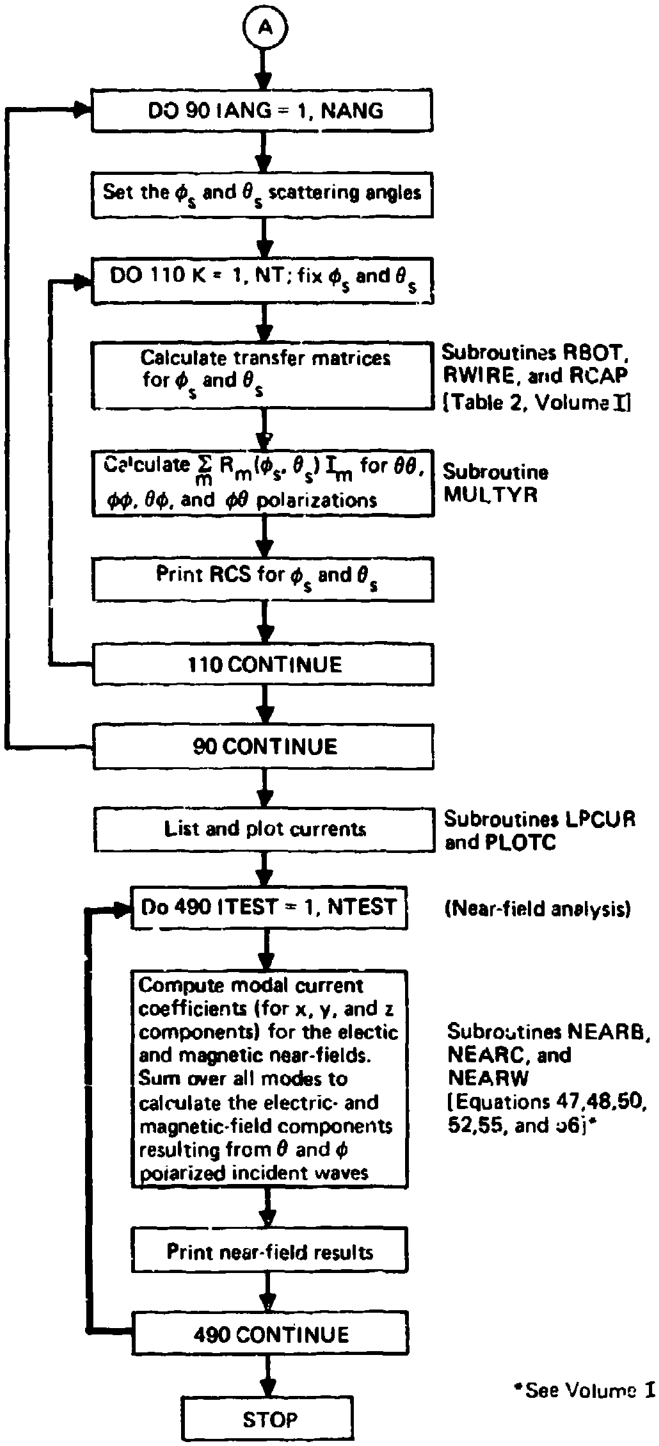


Figure 50. Concluded.

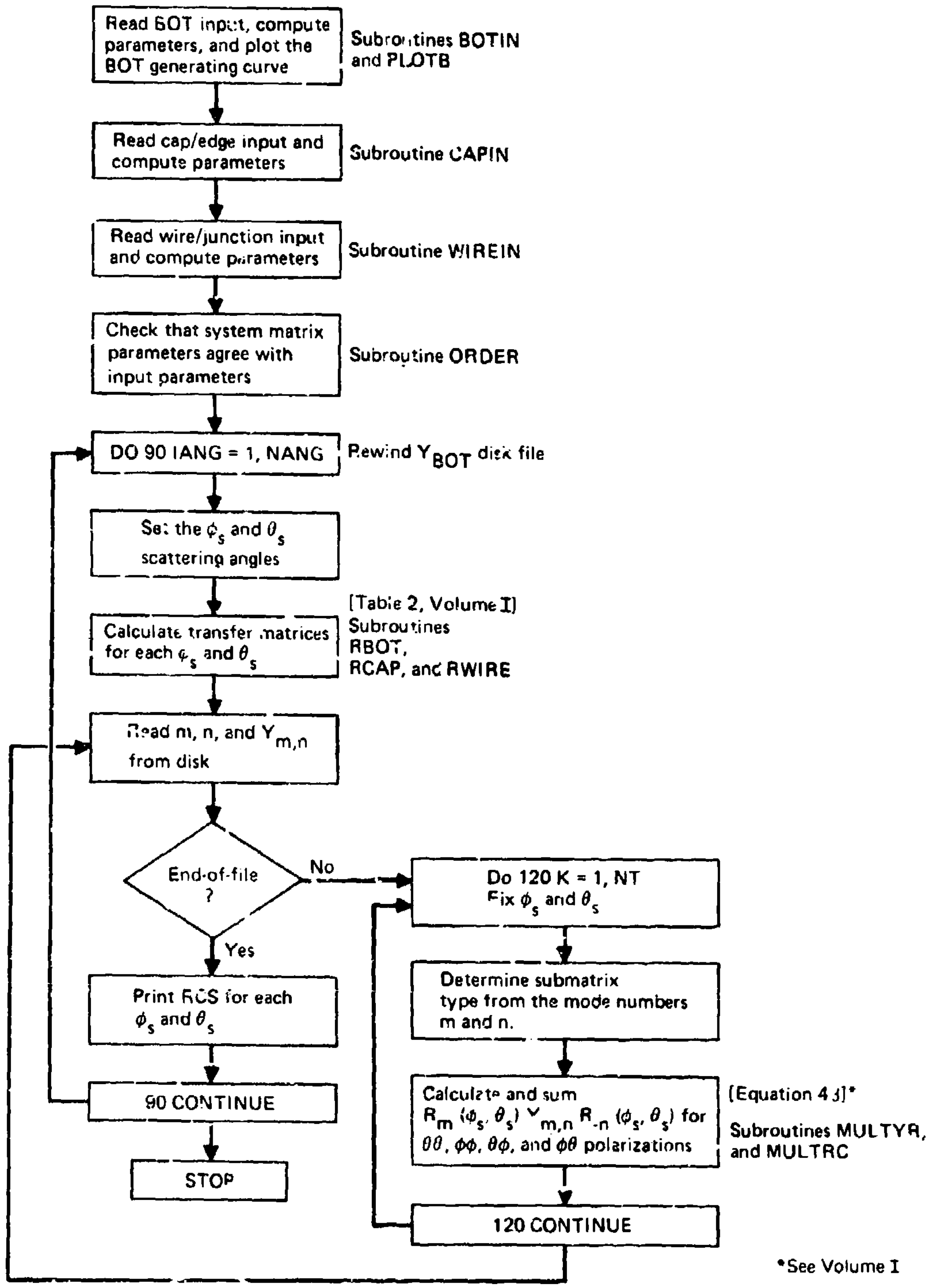


Figure 51. BOTSCM flow diagram.

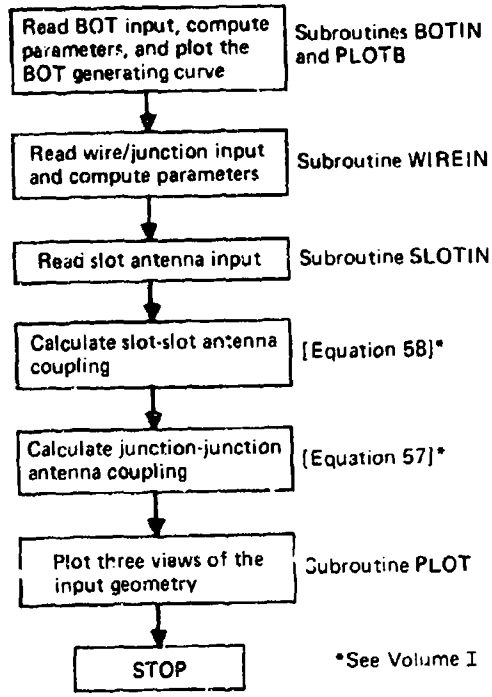


Figure 52. BOTAC flow diagram.

3.6 Subroutine Descriptions

A description of the subroutines, called by each of the A-STAR programs (Figure 1), follows. These subroutines are referenced in the flow diagrams for the program descriptions. The variable descriptions used in these routines are given in Appendix A.

BOTIN - Subroutine BOTIN reads the BOT input geometry from the user input data (see Section 2.3.1), plots the BOT generating curve, and computes all BOT segmentation parameters used in calculations involving the BOT.

CAPIN - Subroutine CAPIN reads the cap/edge input geometry from the user input data (see Section 2.3.2) and computes all cap and edge parameters used in calculations involving the caps and edges.

CSIMP - Subroutine CSIMP is a Simpson integration routine with a calling statement:

CALL CSIMP(F,A,B,DEL,IMAX,SI1,S,N,IER).

This routine computes $S = \int_A^B F(x)dx$ using the method of successive bisections of the interval until either a relative error or DEL is achieved or IMAX bisections have been performed. F must be declared external in the calling program. The following are returned by CSIMP:

S - Approximate value of the integral.

SI1 - Previous approximation to the integral. Convergence has occurred if

$$\left| \frac{S - SI1}{S} \right| < DEL.$$

N - Number of intervals used in computing S.

IER - Error return. IER = 0 indicates that convergence has occurred.

DATAIN - Subroutine DATAIN skips over the BOT and cap/edge input data, reads the wire/junction input geometry from the user input data (see Section 2.3.3), and computes all wire and junction segmentation parameters used in calculations involving the wires and junctions.

GETPQRS - Subroutine GETPQRS retrieves the partitioned system matrix $\begin{bmatrix} P & Q \\ R & S \end{bmatrix}$ from disk, using the following unit numbers:

P^{-1} is read on unit 1

S is read on unit 4

Q is read on unit 2, and if both wires and caps are present in the system matrix, an additional part of Q is read on unit 3.

The matrix R is obtained as the transpose of Q.

GREEN - Subroutine GREEN calculates the Green's function kernel used in the calculation of wire-wire impedance matrix elements.

INVBAN - Subroutine INVBAN is a modification of a standard banded matrix inversion routine using LU decomposition without pivoting, where only the banded portion is stored by columns. Arithmetic operations were replaced by their corresponding matrix operations, and indices were multiplied by LS^2 since the elements were replaced by matrices. The calling statement and arguments follow:

CALL INVBAN(LS,NMODE,NBAND,NZ,A,Z,WORK),

where LS, NMODE and NBAND are described in Appendix A.

INPUT: NZ - Array used for indexing. In a normal banded matrix A, NZ(I) = NZ(I-1) + (the number of zeros below the band in column I-1) + (the number of zeros above the band in column I), where NZ(1) = 0. If A has order n with only the banded portion stored by columns, then A_{ij} will be stored in location n(j-1) + i - NZ(j).

A - Array containing the staircase-type matrix to be inverted, with storage details described above.

Z - Array of length LS^2 used as work area.

WORK - Array of length LS used as work area.

In addition, three variables are passed in common as follows:

COMMON NM,JK(4),LR,

where

NM - Number of triangle functions

JK - Work array of length 4

LR - Work array of length LS.

INVPAR - Subroutine INVPAR inverts a partitioned matrix of the form $\begin{bmatrix} P & Q \\ R & S \end{bmatrix}$, where P^{-1} already exists. The calling statement and arguments follow:

CALL INVPAR(PI,Q,R,S,W,LR,N,M).

INPUT: PI - Matrix containing P^{-1}, and on return it contains the partitioned part of the inverse.

Q,R,S, - Submatrices in the partitioned matrix, and on return they contain the submatrices of the inverse.

W - Complex work array of length max (N,M).

LR - Work array of length M.

N - Order or matrix P.

M - Order of matrix S.

LINEQ - Subroutine LINEQ is a standard matrix inversion routine using Gaussian elimination with partial pivoting, with the following calling statement and arguments:

CALL LINEQ(LL,C,LR),

where

LL - Order of matrix to be inverted.

C - Array containing the matrix to be inverted, stored by columns. On output, C contains the inverted matrix.

LR - Array of length LL used as a work space during the pivoting process.

LIST - Subroutine LIST prints individual $Y_{m,n}$ submatrices on the line printer and writes them to a disk file.

LISTA - Subroutine LISTA prints individual $Y_{m,n}$ submatrices that correspond to wires and/or caps, and writes them to a disk file.

LPCUR - Subroutine LPCUR lists and plots the BOT currents (magnitude and phase as a function of Z/BL) for each triangle function on the body, and then lists cap/edge and wire/junction currents.

NEARB - Subroutine NEARB calculates the electric and magnetic current coefficients for one mode of the BOT current expansion, and for one near-field test point.

NEARC - Subroutine NEARC calculates the electric and magnetic current coefficients for the caps resulting from one near-field test point.

NEARW - Subroutine NEARW calculates the electric and magnetic current coefficients for the wires resulting from one near-field test point.

ORDER - Subroutine ORDER checks that the user input data agree with the parameters contained in the system matrix disk file, and prints the order in which caps and/or wires were added to the system.

PLOT - Subroutine PLOT generates an x vs. y plot on the line printer.

PLOTB - Subroutine PLOTB plots the points on the generating curve of the BOT. Points on the BOT corresponding to triangle function peaks are indicated with a plus sign. The calling statement is

CALL PLOTB(X,Y,N,NR),

where

- X - Array of x coordinates to be plotted
- Y - Array of y coordinates to be plotted
- N - Number of points to be plotted
- NR - Number of line printer rows to use for the y-axis.

The routine uses 51 columns for the x-axis, with the dynamic range on both the x and y axes equal. Hence, depending upon the type of line printer used, NR may have to be adjusted to obtain a plot that is not distorted (i.e., the x and y axes have approximately the same physical length on the line printer output).

PLOTC - Subroutine PLOTC plots the magnitude and phase of the currents on a given BOT triangle function. The calling statement is as follows:

CALL PLOTC(Y1,Y2),

where

INPUT: Y1 - Array containing the current magnitude at 41 equally spaced z coordinates.

Y2 - Array containing the current phase at 41 equally spaced z coordinates.

PUTPQRS - Subroutine PUTPQRS writes the partitioned inverted system matrix to a disk file by submatrices $Y_{m,n}$, where m and n are either BOT mode numbers or pseudo mode numbers corresponding to wires and caps.

RBOT - Subroutine RBOT computes the mode-independent part of the BOT transfer matrices for (ϕ,θ) angles.

RCAP - Subroutine RCAP computes the cap/edge transfer matrices for (ϕ,θ) angles.

RWIRE - Subroutine RWIRE computes the wire/junction transfer matrices for (ϕ,θ) angles.

SBOTIN - Subroutine SBOTIN skips over the BOT geometry input data.

SCAPIN - Subroutine SCAPIN skips over the cap/edge input data.

SLOTIN - Subroutine SLOTIN reads the slot antenna input data (see Section 2.3.4).

VBOT - Subroutine VBOT computes the BOT voltage array for a given mode number resulting from the slot antennas on the BOT.

VWIRE - Subroutine VWIRE reads the wire/junction voltages and generates the wire/junction voltage array.

WIREIN - Subroutine WIREIN reads the wire/junction input geometry from the user input data (see Section 2.3.3) and computes all wire and junction segmentation parameters used in calculations involving the wires and junctions.

ZLIST - Subroutine ZLIST prints impedance matrices on the line printer by submatrices according to the type of current expansions contained in the impedance matrix.

APPENDIX A: DICTIONARY OF COMMON PROGRAM VARIABLES

(Input variables are described in Section 2.3; equation numbers refer to expressions in Volume I; page numbers refer to Volume II)

AC(I) - Area of cap triangle formed by connecting the BOT segment I with the cap center point (XC, YC). The area of the Jth trapezoidal patch on this cap triangle is then given by AC(I)*(RHOC(J+1)**2 -RHOC(J)**2).

ANG - Input array of fixed radiation or scattering angles (page 15).

ANG1 - Input array of starting radiation or scattering angles (page 15).

ANG2 - Input array of ending radiation or scattering angles (page 16).

BK - Wavenumber (meters^{-1}).

BKL - BK*BL.

BL - Half length of BOT (meters).

CB - Array containing modal t- and z-directed currents on the BOT [Equation (2)]. CB [(m + NMODE - 1)*LS + J] contains the t-directed current for mode m on triangle function J. The z-directed current is stored in CB [(m + NMODE -1)*LS + J+NM]. Used in BOTRA.

CBP - Array containing modal t- and z-directed currents on the BOT for a ϕ-polarized incident wave. See variable CB for storage details. Used in BOTSCB and BOTSCM.

CBT - Array containing modal t- and z-directed currents on the BOT for a θ-polarized incident wave. See variable CB for storage details. Used in BOTSCB and BOTSCM.

CC - Array containing t- and ρ-directed currents on the caps and edge currents.

CCP - Array containing t- and ρ-directed currents on the caps and edge currents for a ϕ-polarized incident wave.

CCT - Array containing t- and ρ-directed currents on the caps and edge currents for a θ-polarized incident wave.

CPC(I) - Cosine of ϕ_p angle for BOT generating curve segment I. (See Figure 3 of Volume I.) Used when caps are present.

CV(I) - Cosine of ν_p angle for BOT generating curve segment I. (See Figure 2 of Volume I.) CV(J) corresponds to ν_q on segment J.

CW - Array containing wire and junction currents.

CWP – Array containing wire and junction currents for a ϕ-polarized incident wave.

CWT – Array containing wire and junction currents for a θ-polarized incident wave.

DH(I) – Length of generating curve segment I (meters).

DHW(I) – Length of wire segment I (meters).

DRHOC(I) – Length of normalized radial segment I on the caps.

DTOR – $\pi/180^{\circ}$.

DXW(I) – x coordinate variation for wire segment I (meters).

DYW(I) – y coordinate variation for wire segment I (meters).

DZW(I) – z coordinate variation for wire segment I (meters).

ESC – Array containing electric near-field radiation components of $\vec{E}(r')$ in the x, y, and z directions [Equations (46-50)] stored in ESC(1-3), respectively. Used in BOTRA.

ESCP – Array containing electric near-field scattering components resulting from a ϕ-polarized incident wave [Equations (46-50)]. Used in BOTSCB.

ESCT – Array containing electric near-field scattering components resulting from a θ-polarized incident wave [Equations (46-50)]. Used in BOTSCB.

EO – Input array for slot antenna excitation [Equation (39)] (page 14).

ETA – $\eta = \sqrt{\mu_o/\varepsilon_o} = 376.707\ \Omega$.

EWGHT – Array of weights used for impedance loads on the edges.

G – Array containing the integrated Green's function kernel $G_{m,n}$ [Equations (A-8) to A-12)]. In BOTZSS, G is symmetric with only the upper triangular portion stored by columns from index 1 to (NP - 1)*NP/2.

$G_{i,j}$ is stored in location G[i + (j - 1)*j/2] when i < j.

GB – Array containing the integrated Green's function kernel $\overline{G}_{m,n}$ [Equation (A-6a)]. See variable G for storage details.

GP – Array containing the fields for the NT radiation angles to compute ϕ-polarized gain.

GS – Array containing the integrated Green's function kernel self-terms on the caps.

GT – Array containing the fields for the NT radiation angles to compute θ-polarized gain.

G1 - Array containing the integrated Green's function kernel G_m for caps and wires.

G2 - Array containing the integrated Green's function kernel G_m for caps and wires.

G1E - Array containing the integrated Green's function kernel G_m for edges.

G2E - Array containing the integrated Green's function kernel G_m for edges.

H0 - Array containing the integrated Green's function kernel for the magnetic near fields [Equation (52)].

H1 - Array containing the integrated Green's function kernel for the magnetic near fields [Equation (52)].

HSC - Array containing magnetic near-field radiation components in the x, y, and z directions [Equations (52)-(56)]. HSC = $\vec{H}(r')$, used in BOTRA.

HSCP - Array containing magnetic near-field scattering components resulting from a ϕ-polarized incident wave. HSCP = $\vec{H}(r')$, used in BOTSCB.

HSCT - Array containing magnetic near-field scattering components resulting from a θ-polarized incident wave. HSCT = $\vec{H}(r')$, used in BOTSCB.

IEDGE - Indicates whether the BCT generating curve is open or closed. IEDGE = 0 for closed and 1 for open.

INDJW - Input array indicating which points in the wire array are junction points (page 12).

INDTJ(I) - The wire segment index at which the I-th junction half triangle function starts.

INDTW(I) - The wire segment index at which the I-th wire triangle function starts.

INDW - Input array indicating the wire indices at which each of the NW wires start (page 12).

IPLANE - Input array indicating whether corresponding element of array ANG is a θ or ϕ angle (page 15).

IS - Input array for specifying location of slot antennas. [See Equations (36)-(39).] (page 13).

IUNIF - Indicate whether the BOT generating curve has uniform or nonuniform segmentation.
IUNIF = 1 for uniform segmentation and IUNIF = 0 for nonuniform segmentation.

KG - NP - 1.

LC - Total number of two-dimensional triangle peaks on the caps.

LC2 - 2*LC.

LE - Total number of triangle peaks on the edges.

LR - (NPR-3)/2 = the number of triangle functions on one of the caps in the radial direction.

LS - Order of each $Z_{m,n}$ submatrix. LS = NP - 3.

LSS - LS*LS.

LW - (NPW-3*NW)/2 = the total number of triangle functions on the wires.

LWJ - LW+NJ.

M - Mode number m.

MORD - Two-dimensional array that indicates the order in which wires and caps have been added to the system matrix. MORD(1)=0 if caps are not contained in the system matrix. If caps are contained in the system, MORD(1) contains the pseudo mode number corresponding to the location of the caps in the system matrix (i.e., MORD(1)=NMODE if caps were added first, and MORD(1)=NMODE+1 if caps were added second). Similarly, MORD(2)=0 if wires are not contained in the system matrix, and if wires are contained in the system matrix, MORD(2) contains the psuedo mode number for the wires.

N - Mode number n.

NANG - Input variable. Number of fixed radiation or scattering angles (page 15).

NBAND - Input variable. Number of submatrix diagonal bands used in Z^{-1}_{BOT} (page 9).

NC - Number of caps.

NE - Indicates whether cap/edge terms are included. NE=0 if edge terms are not present, and NE=NC if edge terms are present.

NJ - Number of junctions.

NM - Number of triangle functions on the BOT generating curve.
NM = (NP-3)/2.

NMODE - Input variable. Number of nonnegative modes (page 9).

NM2 - Order of each $Z_{m,n}$ submatrix. NM2=NP-3.

NM4 - NM*4.

NP - Number of points on the BOT generating curve. (See Section 2.3.1.)

NPR - Number of radial points on each cap.

NSP - Input variable. Number of diagonal bands used in BOT impedance matrices (page 9).

NPW - Total number of points on the wires.

NSA - Number of slot antennas on the BOT.

NT - Input variable. Number of radiation and scattering angles (page 15).

NTEST - Input variable. Number of test points for near-fields (page 16).

NW - Number of wires.

PHII - ϕ angle for the incident wave (degrees). PHII = ϕ_i in Equation (43).

PHIR(K) - ϕ angle for the radiated fields (degrees). PHIR(K) = ϕ_r in Equation (32).

PHIS(K) - ϕ angle for the scattered fields (degrees). PHIS(K) = ϕ_s in Equation (43).

RADD(I) - Radius of the I-th junction disk (meters).

RADJ(I) - Radius of the I-th junction wire (meters).

RADW(I) - Radius of I-th wire (meters).

RBP - Array containing the mode-independent portion of the BOT $R_n^{t\phi}$ and $R_n^{z\phi}$ matrices (i.e., with the α term removed) resulting from a ϕ-polarized incident wave. The order of storage is
$\{(R_n^{t\phi})_i,\ i = 1 \text{ to NM}\}$ followed by
$\{(R_n^{z\phi})_i,\ i = 1 \text{ to NM}\}$.
RBP can contain the transfer matrices for several (ϕ, θ) angles. In this case, the starting index is offset by a multiple of 2*NM.

RBT - Array containing the mode-independent portion of the BOT $R_n^{t\theta}$ and $R_n^{z\theta}$ matrices (i.e., with the α term removed), resulting from a θ-polarized incident wave. The order of storage is
$\{(R_n^{t\theta})_i,\ i = 1 \text{ to NM}\}$ followed by
$\{(R_n^{z\theta})_i,\ i = 1 \text{ to NM}\}$.
As in RBP, the starting index can be offset by a multiple of 2*NM.

RC(I) - Radial distance from the center of the cap to the I-th BOT point (meters).

RC1(I) - Radial distance from the center of the cap to the I-th BOT segment (meters).

RCP - Array containing the cap/edge transfer matrices resulting from a ϕ-polarized incident wave. The order of storage is
$\{R_i^{t\phi}$, i = 1 to LC$\}$ followed by
$\{R_i^{\rho\phi}$, i = 1 to LC$\}$ followed by
$\{R_i^{e\phi}$, i = 1, LE$\}$.
RCP can contain the transfer matrices for several (ϕ, θ) angles.
In this case, the starting index is offset by a multiple of 2*LC+LE.

RCT - Array containing the cap/edge transfer matrices resulting from a θ-polarized incident wave. See variable RCP for storage details.

RHOC - Input array of normalized radial coordinates on each cap.

RHOC1 - Normalized radial coordinates for the radial segments on each cap.

RWP - Array containing the wire/junction transfer matrices resulting from a ϕ-polarized incident wave. The order of storage is
$\{R_i^{w\phi}$, i = 1 to LW$\}$ followed by
$\{R_i^{j\phi}$, i = 1 to NJ$\}$.
RWP can contain the transfer matrices for several (ϕ, θ) angles.
In this case, the starting index is offset by a multiple of LW+NJ.

RWT - Array containing the wire/junction transfer matrices resulting from a θ-polarized incident wave. See variable RWP for storage details.

RWGHT - Array of weights to be used for ρ-directed impedance loads on the caps.

SPC(I) - Sine of ϕ_p angle for BOT generating curve segment I. (See Figure 3 of Volume I). Used when caps are present.

SPP - Array containing $\sigma^{\phi\phi}$ for the NT scattering angles [Equation 43)].

SPT - Array containing $\sigma^{\phi\theta}$ for the NT scattering angles [Equation 43)].

STP - Array containing $\sigma^{\theta\phi}$ for the NT scattering angles [Equation (43)].

STT - Array containing $\sigma^{\theta\theta}$ for the NT scattering angles [Equation (43)].

SV(I) - Sine of ν_p angle for BOT generating curve segment I. (See Figure 2 of Volume I.) [Equation (A-3).] SV(J) corresponds to ν_p on segment J.

T - Array containing the values of the triangle functions T_p^t.
T[(K - 1)*4 + p] contains the value of the k-th triangle function

over the p-th segment forming it. $1 \leq p \leq 4$. [Figure 2, Volume I].

TBE - Array containing the values of the edge half-triangle functions on the BOT.

TCE - Array containing the values of the edge half-triangle functions on the cap.

TCR - Array containing the values of the radially directed triangle functions on the caps for ρ-directed currents.

TCT - Array containing the values of the radially directed triangle functions on the caps for t-directed currents.

TEXC - Input array indicates t-excitation on slot antenna (page 14).

THI - θ angle for the incident wave (degrees). THI = θ_i in Equation (43).

THR(K) - θ angle for the radiated fields (degrees). THR(K) = θ_r in Equation (32).

THS(K) - θ angle for the scattered fields (degrees) [Equation (43)].

TJ - Array containing the values of the junction half-triangle functions.

TP - Array containing the values of $\hat{T}_p^t$. The storage method is the same as for T.

TPBE - Array containing derivatives of the half-triangle functions in the TBE array with respect to Z.

TPCE - Array containing derivatives of the half-triangle functions in the TCE array with respect to ρ.

TPCR - Array containing derivatives of the triangle functions in the TCR array with respect to ρ.

TPCT - Array containing derivatives of the triangle functions in the TCT array with respect to ρ.

TPJ - Array containing derivatives of the half-triangle functions in the TJ array with respect to wire length.

TPW - Array containing derivatives of the triangle functions in the TW array with respect to wire length.

TW - Array containing the values of the triangle functions on the wires.

TWGHT - Array of weights to be used for t-directed impedance loads on either the BOT or caps.

TZ - Array containing the values of T_p^z. The storage method is the same as for T.

U - Imaginary number i.

UXJ,UYJ,JZJ - Input arrays containing the x, y, and z components, respectively, of the normal vector to each junction disk.

UXJ1,UYJ1,UZJ1 - Arrays containing the x, y, and z components, respectively, of one of the orthonormal vectors on each junction disk.

UXJ2,UYJ2,UZJ2 - Arrays containing the x, y, and z components, respectively, of one of the orthonormal vectors on each junction disk.

VB - Array of BOT voltages corresponding to mode N. VB(K) contains t-directed voltages V_{ni}^t on triangle function K. VB(K + NM) contains z-directed voltages V_{ni}^z on triangle function K [Equation (37)].

VW - Array of wire voltages.

XB - Input array of x coordinates for BOT (page 9).

XB1(I) - x coordinate for generating curve segment I (meters).

XC - x coordinate of cap center (meters).

XJ(I) - x coordinate of the I-th junction point (meters).

XTEST - Input variable for near-field test point x′ in r′ (page 16).

XW - Array of x coordinates for the wires (meters).

XW1(I) - x coordinate of wire segment I (meters).

Y - Array containing the $Y_{m,n}$ submatrix [Equation (41)]. In the near-field analysis, however, Y contains the measurement matrix ZM. $Y_{m,n}$ is stored by columns.

YB - Input array of y coordinates for BOT (page 9).

YB1(I) - y coordinate for generating curve segment I (meters).

YC - y coordinate of the cap center (meters).

YJ(I) - y coordinate of the I-th junction point (meters).

YTEST - Input variable for near-field test point y′ in r′ (page 16).

YW - Array of y coordinates for the wires (meters).

YW1(I) - y coordinate of wire segment I (meters).

Z - Array containing the impedance matrix stored by columns.

ZBE - Array of z coordinates for the edge term on the BOT surface (meters).

ZC(I) - z coordinate of cap I (meters).

ZE(I) - z coordinate where the edge term for cap I terminates on the BOT surface (meters).

ZEXC - Input array indicates z-excitation on slot antenna (page 14).

ZJ(I) - z coordinate of the I-th junction point (meters).

ZM - Array containing the electric and magnetic modal current coefficients for near-field calculation [Equations (47), (52)]. ZM uses the same storage location as the Y matrix, which is of order LS, stored by columns. Rows 1 through 3 of ZM contain the M-th modal current coefficients for the electric near-field components in the x, y, and z, respectively, at the point (XTEST, YTEST, ZTEST). Similarly, rows 4 through 6 of ZM contain the M-th modal current coefficients for the magnetic near-field components in the x, y, and z directions, respectively.

ZTEST - Input variable for near-field test point z′ in r′ (page 16).

ZW - Array of z coordinates for the wires (meters).

ZW1(I) - z coordinate of wire segment I (meters).

ZWGHT - Array of weights to be used for z-directed impedance loads on the BOT.

Z0(I) - Starting z coordinate for slot antenna I (meters).

Z1(I) - Ending z coordinate for slot antenna I (meters).